Water Quality Assessment of Long, Mica, Opinicon, Sydenham, and Upper Rideau Lakes, 1982.

Rideau Lakes
Fisheries Assessment Unit
Report No. 14

W.G. Smith

N.G. MacLean

Rideau Lakes
Fisheries Assessment Unit
R.R. 2 Sharbot Lake
Ontario K0H 2P0
613 335-2115

Printed in Ontario, Canada

© Government of Ontario, 1985

Ontario
Ministry of Natural Resources

Hon. Vincent G. Kerrio
Minister
Mary Mogford
Deputy Minister

90-05969/

Depletion (of fish stocks) is not, as frequently understood a condition either of recent origin or of temporary nature. ... It would be better to consider depletion as a process and to understand how reduction of native stocks begins in the first place in order to appreciate the nature of the final stage... .

.....

This process has been going on (since early travellers and pioneer settlers first arrived)... . It has been assisted by almost every influence that has come about in the course of social and industrial progress. We have only to run through the list - deforestation, navigation facilities, water supply, pollution, power development, tourist trade and what not - to see how the process of fish extermination works.

.....

Viewing the matter historically, we have (in the southwestern portion of the province) ... a relatively small area which ... sustained ... the first shock of industrial development and depletion.

.....

While this development was going on, and during its advanced stages in the last century, the waters immediately along and to the northward of the pre-Cambrian line began to be accessible and also desirable from the summer visitor's point of view.

The waters involved were the Muskoka Lakes, to some extent the Georgian Bay and the magnificent lakes and streams of the Trent and Rideau systems, ... together with the upper reaches of the St. Lawrence River ... . It is the same waters, generally speaking, that are now in critical condition.

.....

Depletion is a process of long duration which can and in all Ontario situations is likely to be greatly accelerated (in the future).

- excerpt from Macdiarmid F., B.A. Bensley and C.A. Candee. 1930. Report of Special Committee on the Game Fish Situation. Legislative Assembly of Ontario Sessional Paper, No. 54. pp. 12-16. Printed and Published by Herbert H. Ball, Printer to the King's Most Excellent Majesty.

TABLE OF CONTENTS

		Page
	ABSTRACT	iii
1.	INTRODUCTION	1
2.	STUDY AREA	3
3.	METHODS	6
	3.1 Sampling design	6
	3.2 Field collection	7
	3.2.1 Routine profiling	7
	3.2.2 Standard chemicals	7
	3.2.3 Heavy metals	7
	3.2.4 Chlorophyll	7
	3.2.5 Nutrients	7
	3.2.6 Runoff studies	8
	3.3 Laboratory analysis	8
	3.4 Data interpretation	8
	3.4.1 Water quality criteria	8
	3.4.2 Optimum habitat	8
	3.4.3 Missing data	9
4.	RESULTS AND DISCUSSION	12
	4.1 Long Lake	12
	4.1.1 Routine profiling	12
	4.1.2 Standard chemicals	12
	4.1.3 Heavy metals	12
	4.1.4 Chlorophyll	12
	4.1.5 Nutrients	12
	4.2 Mica Lake	18
	4.2.1 Routine profiling	18
	4.2.2 Standard chemicals	18
	4.2.3 Heavy metals	18
	4.2.4 Chlorophyll	18
	4.2.5 Nutrients	18
	4.3 Opinicon Lake	24
	4.3.1 Routine profiling	24
	4.3.2 Standard chemicals	24
	4.3.3 Heavy metals	24
	4.3.4 Chlorophyll	24
	4.3.5 Nutrients	24
	4.4 Sydenham Lake	30
	4.4.1 Routine profiling	30
	4.4.2 Standard chemicals	30
	4.4.3 Heavy metals	30
	4.4.4 Chlorophyll	30
	4.4.5 Nutrients	30
	4.5 Upper Rideau Lake	41
	4.5.1 Routine profiling	41
	4.5.2 Standard chemicals	41
	4.5.3 Heavy metals	41
	4.5.4 Chlorophyll	41
	4.5.5 Nutrients	41
	4.5.6 Runoff studies	42
5.	RECOMMENDATIONS	49
6.	ACKNOWLEDGEMENTS	50
7.	REFERENCES	51
8.	APPENDICES	55

ABSTRACT

In 1982, the Rideau Lakes Fisheries Assessment Unit monitored the water quality of five warmwater type lakes, ie. Long, Mica, Opinicon, Sydenham and Upper Rideau Lakes.

The study was designed to: 1) document a water quality baseline for the RLFAU type lakes; 2) establish long-term monitoring to identify water quality trends; 3) monitor the effects of specific water quality related stresses on fish habitats and communities.

Field sampling was divided into six main categories, ie. routine profiling, standard chemicals, heavy metals, nutrients, chlorophyll and runoff studies. The resulting data were examined in light of established criteria and the literature.

The following summarizes our findings:

- Long, Sydenham, and Upper Rideau Lakes exhibited a well defined thermocline with low, hypolimnetic oxygen concentrations during the summer months. Mica and Opinicon Lakes did not thermally stratify.
- the concentration of iron in bottom samples at Upper Rideau Lake exceeded criteria during the spring.
- generally, mean total phosphorous concentrations in the euphotic zone during the ice free period exceeded the level recommended for maximum protection against aesthetic deterioration but were below those causing nuisance algal blooms. However, summer phosphorous concentrations at both Sydenham Lake Station S1, and Upper Rideau Lakes were capable of supporting nuisance algal growth. Most lakes showed a buildup of nutrients in the hypolimnion during the summer months, an indicator of eutrophication.
- spring runoff did not depress pH or alkalinity below critical levels at the Westport walleye spawning channel.

1. INTRODUCTION

The Rideau Lakes Fisheries Assessment Unit (RLFAU) water quality monitoring program began in 1981 (MacLean and Smith 1981).

The objectives of the program were:

1) to document a water quality data baseline for the RLFAU type lakes;
2) to establish long term monitoring to identify water quality trends; and
3) to monitor the effects of specific water quality related stresses on fish habitat and communities.

In 1982, water quality monitoring was limited to the five warmwater lakes of the 10 RLFAU type lakes (Fig. 2.1), ie. Long, Mica, Opinicon, Sydenham, and Upper Rideau Lakes. This report documents the results of these investigations.

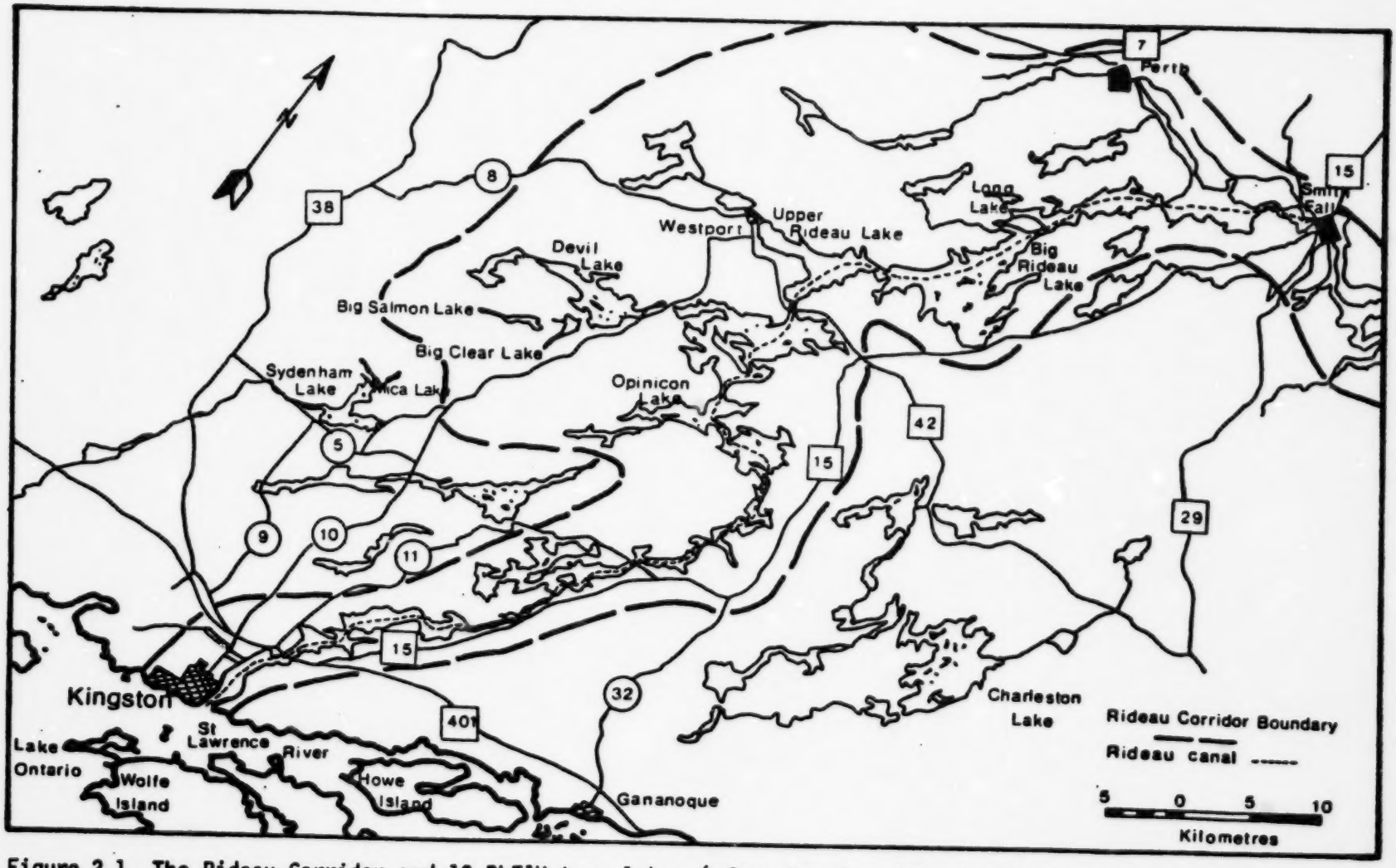


Figure 2.1 The Rideau Corridor and 10 RLFAU type lakes (after Canada - Ontario Rideau - Trent - Severn Study Committee 1971).

2. THE STUDY AREA

The study lakes are located in three tertiary watershed divisions, ie. the Rideau River, Western St. Lawrence Tributaries and Lake Ontario Tributaries divisions (Fig. 2.2).

Long, Mica, and Opinicon Lakes are all located on the Canadian Shield. Sydenham Lake lies near the northeast border of the Napanee limestone plain while Upper Rideau occupies a depression between the Canadian Shield and Smiths Falls limestone plain (Fig. 2.3).

The fish communities, physical characteristics, and stresses of the lakes are summarized in Table 2.1. Values for total dissolved solids (TDS), the morphoedaphic index (MEI), and potential yield were recalculated using 1982 water quality data contained in this report and the revised formula for conversion of conductivity data to TDS, in which,

TDS = 0.666 COND 25 C. (Gale and Goodchild 1982).

Table 2.1 Characteristics of the five study lakes (from Schlesinger, Ridout and MacLean, 1984).

Lake	Lake Community	Area	Mean Depth	TDS	T/O_2	MEI	Yield	Stresses Fishing	Stresses EAWPI
Long	0604	85.0	5.0	116.5	SLO	23.3	5.62	010	10000
Mica	0404	23.9	1.4	140.5	NST	100.4	10.78	010	00000
Opinicon	0604	796.7	2.5	122.0	NST	48.8	7.81	031	10111
Sydenham	0604	450.8	4.8	168.0	SLO	24.7	5.76	030	10010
Upper Rideau	0704	1362.8	6.1	150.0	SLO	18.5	5.07	031	10111

Definition of Columns -

Lake Community: First two columns = major community. 04 = northern pike; 06 = northern pike-smallmouth bass; 07 = northern pike-smallmouth bass-walleye.
Last two columns = minor community. 04 = largemouth bass.

Area = surface in hectares (ha).

Mean Depth = mean depth in metres (m).

TDS = total dissolved solids (mg/l) based on the lowest observed summer conductivity (1982 water quality data).

T/O_2 = temperature/oxygen; ie. SLO = stratified, low oxygen; SHO = stratified, high oxygen; NST = not stratified.

MEI = metric morphoedaphic index (ppe/m).

Yield = Ryders annual yield estimated for Northern Great Lakes - St. Lawrence Watershed (kg/ha/yr) (MNR 1982).

Stresses = Fishing: first column = no exploitation, second column = sport exploitation and third column = commercial exploitation; where 0 = none, 1 = low, 2 = medium, and 3 = high.
Other: presence = 1 or absence = 0, of E = eutrophication, A = acidification, W = water levels, P = physical alterations and I = introductions. (Note: here introductions refer to exotic species. Various game fish have been successfully introduced to these waters in the past).

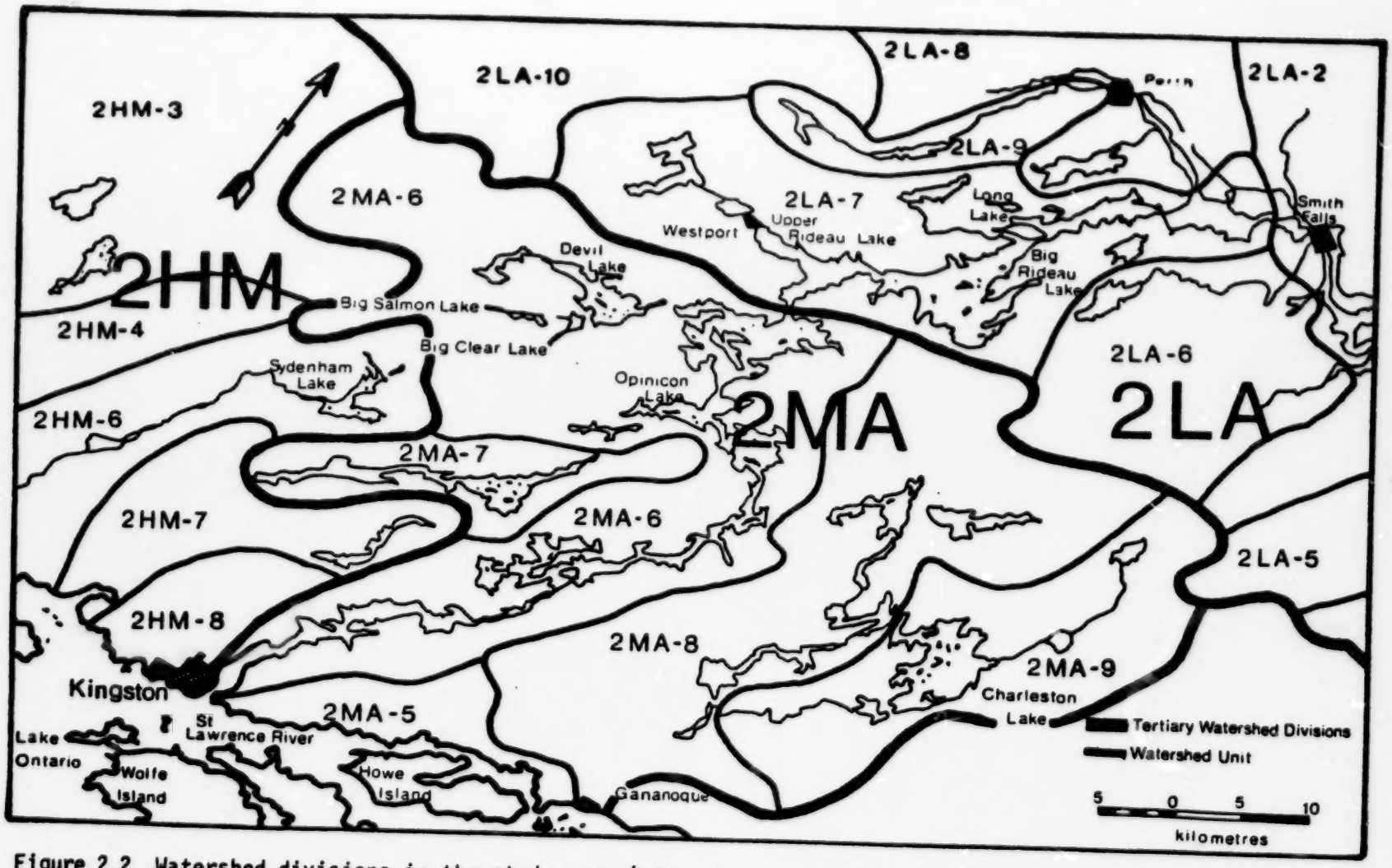


Figure 2.2 Watershed divisions in the study area (after Ontario Ministry of Natural Resources 1973). Watershed codes: 2MA = Western St. Lawrence Tributaries, 2HM = Lake Ontario Tributaries, 2LA = Rideau River.

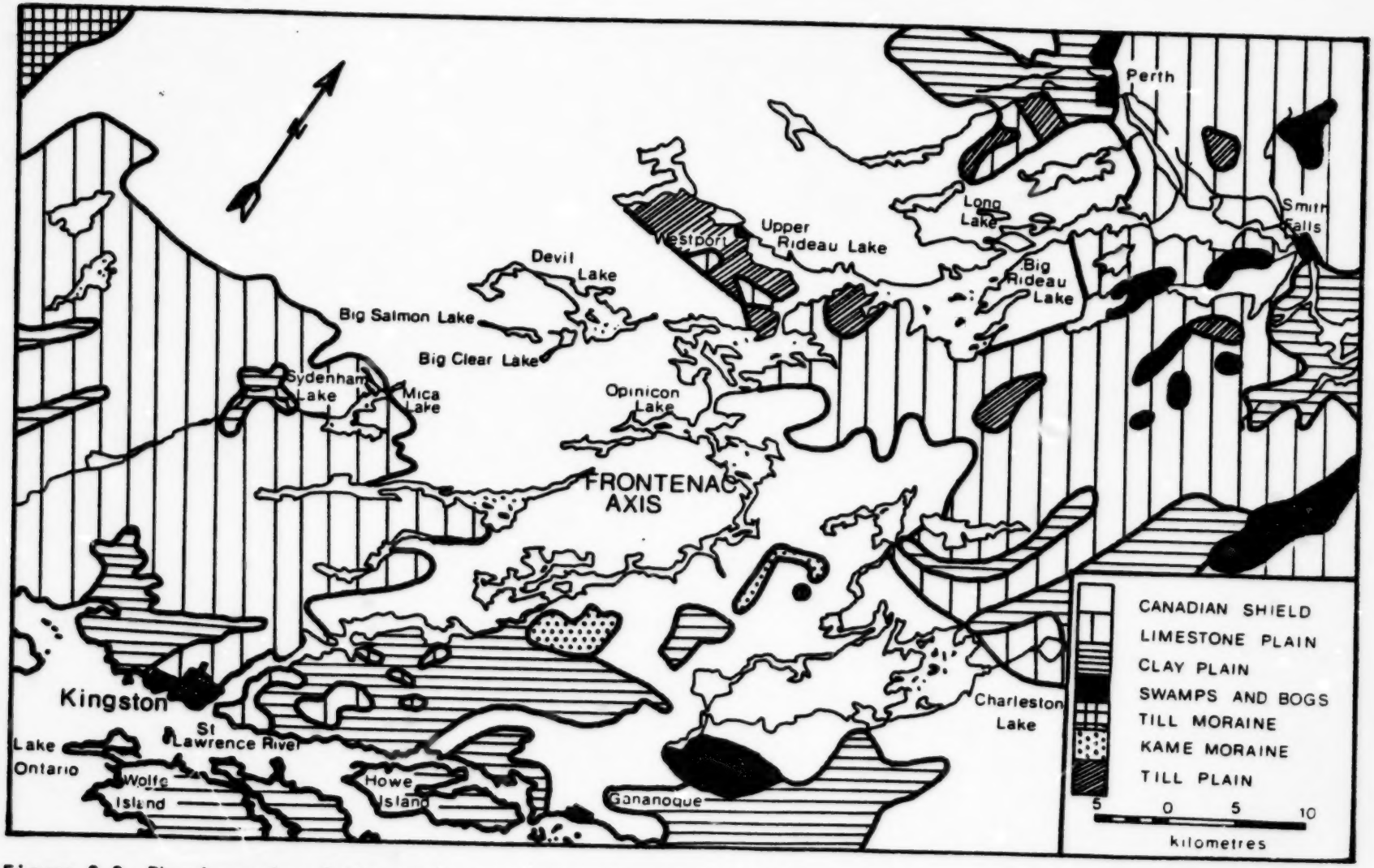


Figure 2.3 Physiography of the study area (after Chapman and Putman 1966).

3. METHODS

3.1 SAMPLING DESIGN

Water quality sampling locations were selected according to criteria for site selection listed in the Aquatic Habitat Inventory Survey Manual (Dodge et al. 1981). The water quality stations were assigned Universal Transverse Mercator grid locations (Energy, Mines and Resources 1978 and 1979 a,b) and given numbers to correspond with the lake basin (Table 3.1).

The sampling program was divided into six main categories: routine profiling, standard chemicals, heavy metals, nutrients, chlorophyll, and runoff studies (MacLean and Smith 1982). Routine profiling, standard chemical, and nutrient data were collected quarterly at every station in order to identify seasonal trends, ie. spring (mid-May), summer (mid-July), fall (mid-September), and winter (mid-January). Chlorophyll samples were collected during the ice-free season only. Heavy metals were sampled once annually (mid-January), at the deepest basin of each lake, while spring runoff was sampled only at Upper Rideau Lake.

Table 3.1 Universal Transverse Mercator grid locations for RLFAU water quality stations on Long, Mica, Opinicon, Sydenham and Upper Rideau Lakes.

Lake	Station	Grid Reference
Long Lake	L1	VE 013604
Mica	M1	UE 770240
Opinicon Lake	O1	UE 945344
Sydenham Lake	S1	UE 755194
	S2	UE 761225
Upper Rideau	UR1	UE 940488

3.2 FIELD COLLECTION

3.2.1 Routine profiling

A Hydrolab 8000™ unit was used to collect routine profiles of temperature, dissolved oxygen, conductivity, pH, and oxidation-reduction potential (ORP). Measurements were recorded at the surface and at 1-m intervals to 20 m, then at 4-m intervals to 1 m above bottom (MacLean and Smith 1982). A Yellow Springs Instruments Model 54 ARC temperature-oxygen meter was used as a backup unit. As such, in the case of equipment malfunction, pH, ORP, and conductivity data are not available.

Water level, air temperature, secchi disc depth, wind direction, cloud cover, and surface conditions were also recorded at each station.

3.2.2 Standard chemicals

A brass Kemmerer bottle was used to collect 1000-ml grab samples from 2 m below the surface and 1 m above bottom. The samples were taken to Ontario Ministry of the Environment (MOE), Kingston, where they were analyzed for hardness (as $CaCO_3$), total fixed alkalinity (TFA) (as $CaCO_3$), iron (as Fe), chloride (as Cl), laboratory pH, conductivity, total dissolved solids (TDS), sodium (as Na), calcium (as Ca), magnesium (as Mg), sulphate (as SO_4), and colour.

3.2.3 Heavy metals

Heavy metal samples were collected 1 m above bottom, placed in 500-ml acid-washed bottles and fixed with 10-12 drops of HNO_3. The samples were taken to MOE, Kingston and forwarded to the Rexdale Laboratories for aluminum, iron and manganese analysis.

3.2.4 Chlorophyll

Chlorophyll samples were collected by lowering a 1000-ml glass sample bottle in a metal can through the euphotic zone (twice the secchi disc depth). Samples were fixed with 1 ml $MgCO_3$ and kept cool in the dark. The samples were analyzed by MOE, Rexdale for chlorophyll *a*.

3.2.5 Nutrients

Nutrient samples were collected from the euphotic zone in the same manner as chlorophyll. In addition, a Kemmerer bottle was used to collect grab samples 1 m above the bottom. Samples were placed in 150-ml polystyrene bottles, allowing 2.5 cm for expansion upon freezing. Frozen samples were transported to MOE,

Kingston for analysis of ammonia (as NH_3), total Kjeldahl nitrogen (TKN), nitrite (as NO_2), nitrate (as NO_3), total phosphorous (as P), and dissolved reactive phosphorous (as P). During winter sampling, the euphotic zone nutrient samples were replaced by surface samples, collected in conjunction with the standard chemical sample.

3.2.6 Runoff samples

The Westport inflow channel was selected as a runoff sampling location (Appendix 8.1). Historically, this site is the preferred spawning location for walleye in Upper Rideau Lake. Over the last two decades this walleye population has progressively declined due to recruitment failure (Raine 1970). Although this failure has been largely attributed to loss of suitable spawning habitat, acid runoff during the spring freshet has been proposed as another possible limiting factor.

A 450-ml runoff sample was collected during the walleye spawning run from mid-channel at 1.5-m depth, using a brass Kemmerer bottle.

3.3 LABORATORY ANALYSIS

All laboratory analyses were provided by MOE Southeastern Region, Kingston and the Limnology and Toxicity Section, Rexdale. MOE (1981a) describes the analytical methods used for individual parameters.

3.4 DATA INTERPRETATION

3.4.1 Water quality criteria

Criteria are maximum levels of toxicants or other substances that can be considered safe for a particular use over extended periods of time. They are based strictly on scientific evidence and are usually proposed by a group of scientists brought together by some agency, eg. U.S. Environmental Protection Agency (EPA)(1977). Table 3.1 lists criteria for most parameters discussed in this report.

Due to the inconclusiveness of bioassay data for some parameters, not all of the criteria listed in Table 3.2 are accepted as agency objectives or standards. In these cases, we have cited levels for protection of warmwater species from the literature.

3.4.2 Temperature and oxygen requirements

Smith and MacLean (1984) discussed oxygen-temperature data

for five RLFAU coldwater type lakes with respect to optimum habitat for lake trout[1], ie. that volume of the water column above the 6 mg/l oxygen level and below 10 C. However, surface water temperatures on these warmwater lakes generally are well below lethal levels for warmwater species, usually approaching both preferred and optimum values (Table 3.3).

Oxygen requirements vary with temperature. Ontario objectives for protection of warm water biota range from 7 mg/l at 0 C to 4 mg/l at 20 C (MOE 1978a).

3.4.3 Missing data

In the following data presentation, missing data is reported under two broad categories: "sampling error" denotes missing data due to improper field techniques, field equipment malfunction, or sample contamination; "no results" denotes the case in which no analytical results are reported for a particular sample due to time expiration, lab equipment malfunction, or reporting problems.

Whenever possible, missing data is interpreted in light of other indices or background information.

Heavy metals - Concentrations of aluminum, manganese, and iron (determined from a single water sample from each lake) generally exceeded recommended criteria. MOE, Kingston considers these results to be anomalous and suggests that the samples, collected 1 m above bottom, may have contained particulate matter (R. Genge, personal communication). As such, we have not reported the data for these parameters.

[1] Common names used throughout this report conform to Bailey et al, (1970).

Table 3.2 Water quality criteria for protection of the aquatic environment.
LC50 = lethal concentration that caused death to 50% of test organisms.

Parameter	Criteria
Oxygen	- Dissolved oxygen concentrations should be > 4ppm at 20 C for warmwater biota (MOE 1978a).
Conductivity	- Waters with a conductivity < 35 umhos/cm at 25 C have a significant potential for acidification (MOE 1979).
pH	- Should be within range of 6.5 - 8.5 (MOE 1978a).
Hardness	- Water with hardness < 120 mg/l can be deemed desirable for most uses. Only if hardness exceeds 500 mg/l can the water be labelled undesirable for both industrial and domestic uses (Environment Canada 1979).
Alkalinity	- Waters with an alkalinity concentration < 15 mg/l have a significant potential for acidification (MOE 1978a). Dillon (1981) states that waters with an alkalinity concentration > 25 mg/l are definitely not sensitive.
Iron	- The concentration of iron in an unfiltered sample should not exceed 0.3 mg/l to protect aquatic life (MOE 1978a).
Chloride	- Concentrations as low as 400 mg/l are lethal to trout (McKee and Wolf 1971).
Aluminum	- In most natural waters, the ionized or potentially ionizable aluminum would be in the form of anionic or neutral precipitates; concentrations of 0.1 mg/l or greater are deleterious to growth and survival of fish (MOE 1978a).
Chlorophyll a	- Lakes with chlorophyll a concentrations of 0-2 ug/l are usually oligotrophic; 2-4 ug/l, mesotrophic; and > 4 ug/l, eutrophic (MOE 1981b).
Ammonia	- Concentrations of unionized ammonia should not exceed 0.02 mg/l for protection of aquatic life (MOE 1978a). Levels > 0.1 usually indicate anthropogenic inputs (Environment Canada 1979). (Note: $[NH_3]$ is both temperature and pH dependent.)
Kjeldahl nitrogen	- Although no specific guidelines, in general, waters that are not influenced by excessive organic inputs range from 0.1 to 0.5 mg/l (Environment Canada 1979).
Nitrite	- < 0.06 mg/l for the protection of salmonids (Thurston et al. 1979).
Nitrate	- Although LC50 is at 5800 mg/l, the best growth for chinook salmon, Oncorynchus tshawytscha, occurs at < 25 mg/l (Westin 1974).
Total phosphorous	- A high level of protection against aesthetic deterioration will be provided by an average total phosphorous concentration for the ice free period of <= 0.01 mg/l.
	- To avoid nuisance concentrations of algae in lakes, the average total phosphorous concentration for the ice free period should not exceed 0.02 mg/l (MOE 1978a).

Table 3.3 Upper incipient lethal (UIL), optimum and preferred temperatures (C) for northern pike, smallmouth bass, largemouth bass, and walleye. (Adapted from Chamberlain et al. 1980.)

Species	Temperature			
	UIL	Growth Optimum	Reproductive Optimum	Preferred (field)
Northern pike[1]	33.5	21.0	12.0	-----
Smallmouth bass[2]	32.0	26.0	17.0-18.0	21.4
Largemouth bass[3]	36.4	27.0	18.9-20.0	26.5-32.0
Walleye[4]	31.6	22.0	6.0	20.6

[1] Northern pike references: Casselman (1978).
[2] Smallmouth bass references: Robbins and MacCrimmon (1974); Horning and Pearson (1973); Breder and Rosen (1966); Ferguson (1958).
[3] Largemouth bass references: Hart (1952); Coutant (1975); Neill (1971).
[4] Walleye references: Smith and Koenst (1975); Ferguson (1958).

4. RESULTS AND DISCUSSION

4.1 LONG LAKE

Water quality was sampled on January 26, May 5, July 7 and September 20, 1982.

4.1.1 Routine profiling

Quarterly temperature and oxygen profiles for Long Lake are shown in Figures 4.1 and 4.2. The lake had a well defined thermocline throughout the summer months with dissolved oxygen concentrations dropping below 4 mg/l at depths greater than 8 m for the period from July to September.

Levels of pH, at all depths and seasons were within the recommended range (Table 4.1).

4.1.2 Standard chemicals

The concentrations of all standard chemicals were below suggested criteria (Table 4.2).

4.1.3 Heavy metals

- see Section 3.4.3.

4.1.4 Chlorophyll

Chlorophyll a results were 2.2, 2.0, and 1.5 ug/l respectively (mean 1.9 ug/l), suggesting that Long Lake is in the latter stages of an oligotrophic lake (Table 4.3). More sampling dates would give a more representative mean, probably tending to mesotrophy.

4.1.5 Nutrients

Total phosphorous concentrations in the euphotic zone during July and September sampling exceeded the level recommended for a high level of protection against aesthetic deterioration, but were still below those supporting nuisance algal blooms (Table 4.4).

Kjeldahl nitrogen levels in samples collected 1m from bottom exceeded criteria throughout the year, reflecting both decomposition of organic material and constant recirculation from the nutrient-rich organic detritus on the bottom.

There was a buildup of most nutrients in the hypolimnion over the summer months, an indicator of eutrophication (Table 4.4) (Edmondson 1979).

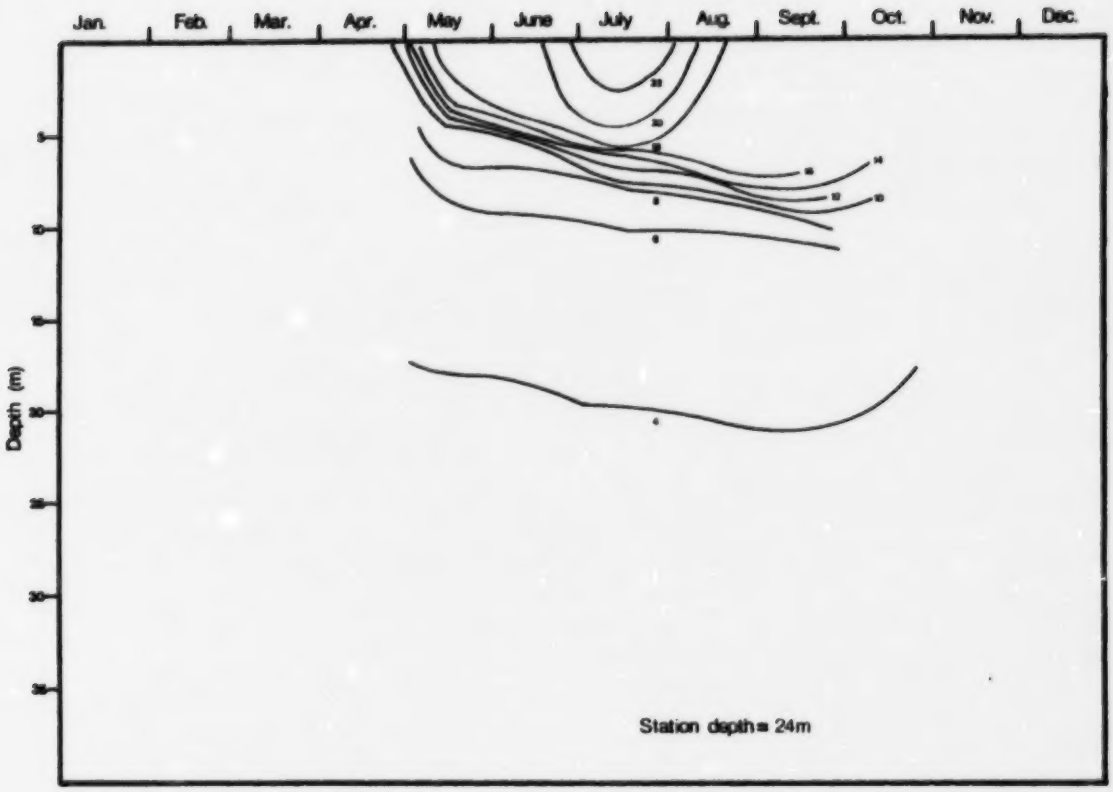


Figure 4.1 Temperature (^{o}C) isotherms at Station L1, Long Lake, 1982.

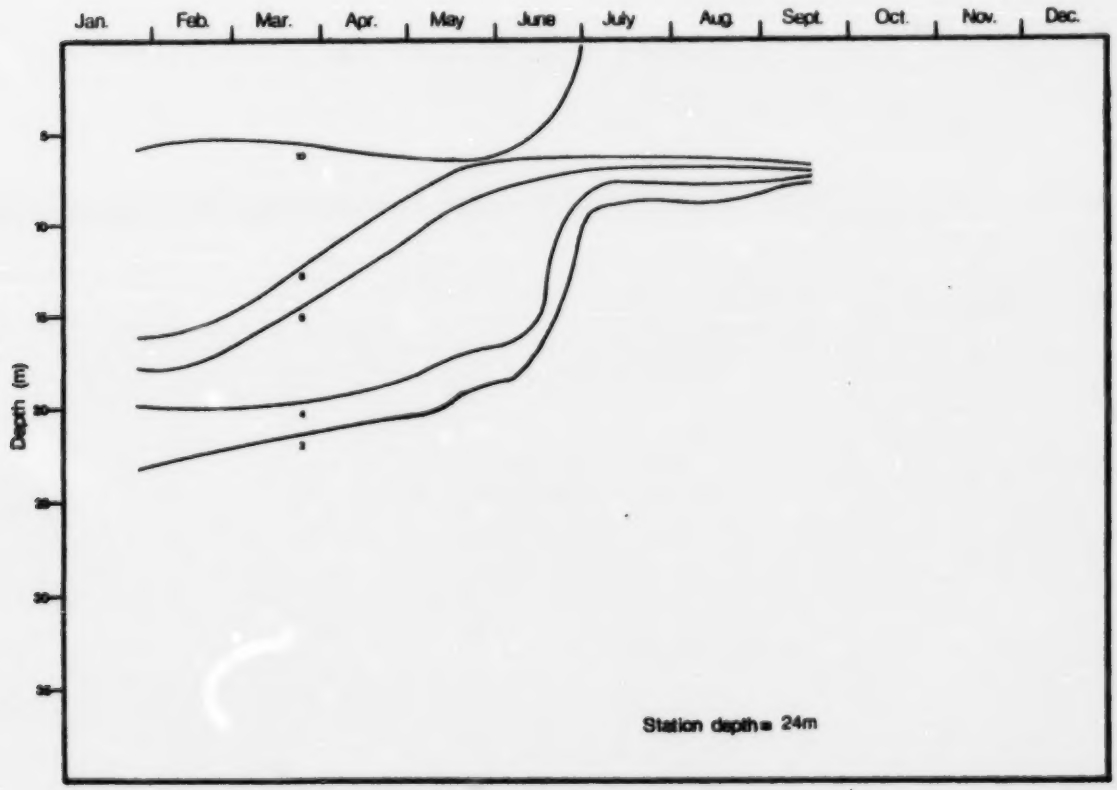


Figure 4.2 Oxygen (mg/l) isopleths at Station L1, Long Lake, 1982.

Table 4.1 Routine profiling of pH at Station L1, Long Lake, 1982.

Depth (m)	pH			
	1982.01.26	1982.05.18	1982.07.07	1982.09.20
Surface	----	8.31	8.24	8.14
1	7.80	8.32	8.22	8.12
2	7.76	8.32	8.22	8.12
3	7.74	8.32	8.17	8.10
4	7.70	8.27	8.15	8.09
5	7.64	8.24	7.99	8.07
6	7.59	7.67	7.44	7.93
7	7.53	7.48	7.26	7.78
8	7.48	7.36	7.12	6.90
9	7.46	7.32	7.02	6.88
10	7.45	7.30	6.99	6.89
11	7.42	7.26	6.97	6.90
12	7.41	7.28	6.98	6.90
13	7.39	7.26	6.99	6.95
14	7.37	7.27	6.96	6.97
15	7.36	7.26	6.99	6.97
16	7.31	7.23	6.97	6.97
17	7.28	7.20	6.98	6.98
18	7.17	7.18	6.98	6.98
19	7.13	7.15	6.98	6.97
20	7.08	7.09	6.97	6.94
21	----	7.07	6.96	----
22	----	7.08	6.94	----
23	6.67	----	----	6.68

Table 4.2 Standard chemical sampling at Station L1, Long Lake, 1982[1].
* denotes "sampling error".
S denotes surface sample.
B denotes bottom sample.

Parameter		Sampling Date			
		1982.01.26	1982.05.18	1982.07.07	1982.09.20
Hardness	S	94	88	90	98
	B	103	92	70	102
Alkalinity	S	86	80	82	85
	B	101	91	72	104
Fe	S	<0.05	0.10	<0.05	0.10
	B	0.05	0.05	0.05	0.20
Cl	S	2.0	2.5	3.3	2.5
	B	1.0	2.8	3.0	3.5
pH	S	7.5	8.0	8.1	8.0
	B	7.1	7.3	7.9	7.3
Conductivity at 25 C (umhos/cm)	S	195	180	175	175
	B	215	200	145	205
TDS	S	127	117	114	114
	B	140	130	94	133
Na	S	3.7	1.9	2.1	1.7
	B	2.5	2.1	2.1	2.0
Ca	S	29	29	30	27
	B	32	30	21	29
Mg	S	4.8	4.0	3.8	7.3
	B	5.8	4.0	4.3	7.3
SO_4	S	9	*	*	8
	B	6	*	*	8
Colour (Hazen)	S	20	14	15	15
	B	22	18	12	26

[1] All concentrations expressed in mg/l unless stated otherwise.

Table 4.3 Chlorophyll sampling at Station L1, Long Lake, 1982[1].

Parameter	Sampling Date		
	1982.05.18	1982.07.07	1982.09.20
Chlorophyll *a*	2.2	2.0	1.5
Secchi (m)	3.1	3.8	4.0

[1] All concentrations in ug/l.

Table 4.4 Nutrient sampling at Station L1, Long Lake, 1982[1].
* denotes "sampling error".
S denotes surface sample.
E denotes euphotic zone composite sample.
B denotes bottom sample.

Parameter		Sampling Date			
		1982.01.26	1982.05.18	1982.07.07	1982.09.20
NH_3	S	0.10			
	E		*	0.01	0.01
	B	0.57	*	0.65	1.55
TKN	S	0.56			
	E		*	0.43	0.44
	B	1.10	*	1.05	1.25
NO_2	S	0.002			
	E		*	<0.002	<0.002
	B	0.002	*	<0.002	0.004
NO_3	S	<0.02			
	E		*	<0.02	<0.02
	B	<0.02	*	<0.02	<0.02
Total P	S	0.034			
	E		*	0.012	0.012
	B	0.096	*	0.094	0.210
Sol. P	S	0.004			
	E		*	0.002	0.002
	B	0.060	*	0.060	0.210

[1] All concentrations in mg/l.

4.2 MICA LAKE

Water quality was sampled on January 27, May 20, July 13, and September 21, 1982.

4.2.1 Routine profiling

Quarterly temperature and oxygen profiles for Mica Lake are illustrated in Figures 4.3 and 4.4. The lake did not stratify during the summer months and oxygen levels remained high throughout the year.

There was a progressive increase in pH at all depths over the summer months (Table 4.5). Stiebel (1975) attributed this seasonal fluctuation to increased silica and alkalinity.

4.2.2 Standard chemicals

Water hardness, expressed as an equivalent of $CaCO^3$, exceeded the optimum range (<=120 mg/l) during January sampling. However, concentrations were still deemed suitable for domestic and industrial uses.

The concentrations of all other standard chemicals were below suggested criteria (Table 4.6).

4.2.3 Heavy metals

- see Section 3.4.3.

4.2.4 Chlorophyll

Chlorophyll a was only reported for July sampling (Table 4.7). However, secchi disk measurements, suggest that Mica Lake is mesotrophic (MOE 1981b).

4.2.5 Nutrients

The mean total phosphorous concentration in the euphotic zone during the ice-free period (0.016 mg/l) exceeded the level recommended for a high level of protection against aesthetic deterioration but was still below those causing nuisance algal blooms (Table 4.8).

The low spring and high fall and winter concentrations of nutrients reflect the natural production and subsequent decomposition of organic material. The high year-round concentrations of Kjeldahl nitrogen result from constant recirculation from the nutrient-rich organic detritus covering the lake bottom.

Mica Lake has remained relatively free of nutrient loading from cultural sources due to the lack of arable land or access roads. The lake is apparently in a natural state of eutrophication, production still limited by phosphorous concentrations.

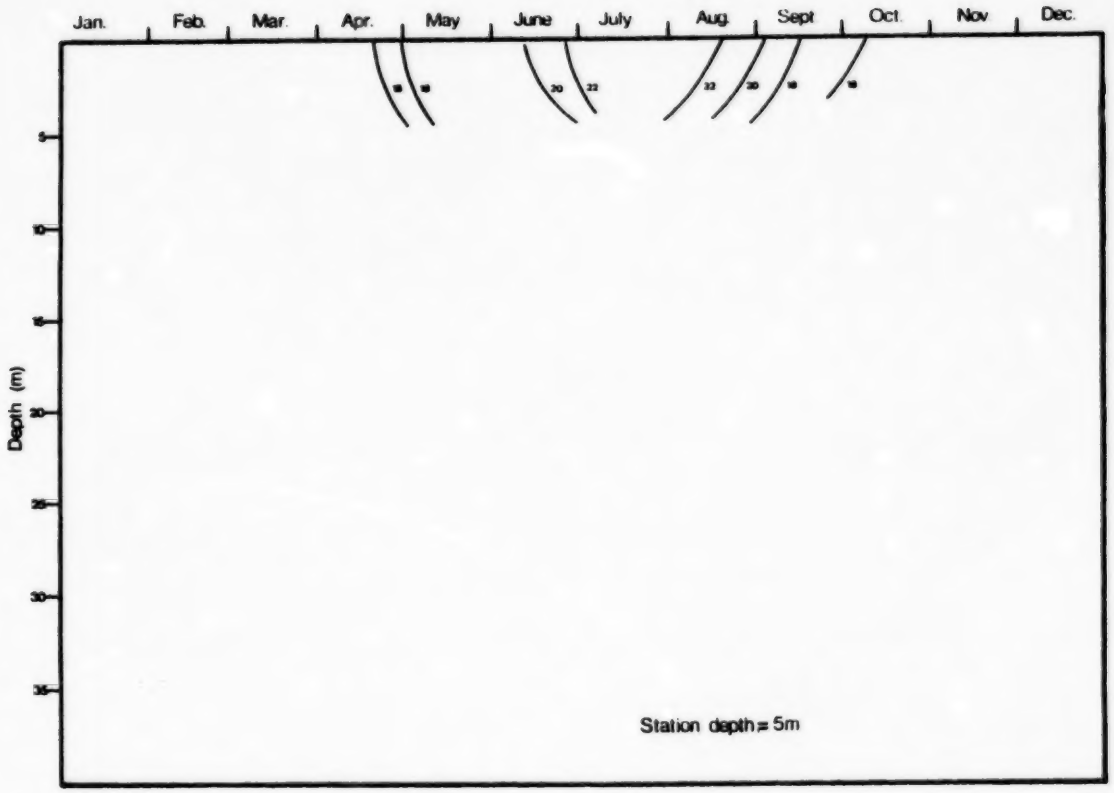


Figure 4.3 Temperature (^{o}C) isotherms at Station M1, Mica Lake, 1982.

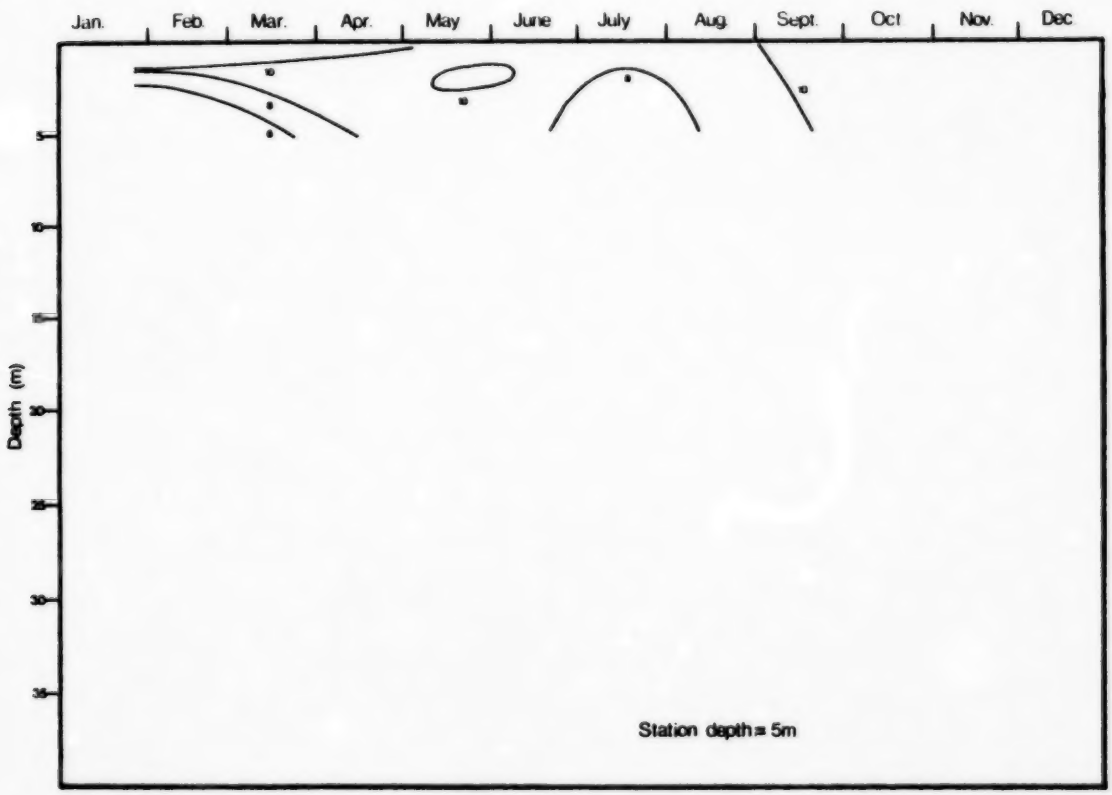


Figure 4.4 Oxygen (mg/l) isopleths at Station M1, Mica Lake, 1982.

Table 4.5 Routine profiling of pH at Station M1, Mica Lake, 1982.
* denotes "sampling error".

Depth (m)	pH			
	1982.01.27	1982.05.20	1982.07.13	1982.09.21
Surface	----	7.68	8.25	8.82
1	7.68	*	8.25	8.80
2	7.42	*	8.23	8.80
3	7.35	*	8.17	8.85
4	7.32	*	8.12	*

Table 4.6 Standard chemical sampling at Station M1, Mica Lake, 1982[1].
* denotes sampling error.
S denotes surface sample.
B denotes bottom sample.

Parameter		Sampling Date			
		1982.01.27	1982.05.20	1982.07.13	1982.09.21
Hardness	S	140	106	110	106
	B	148	106	110	96
Alkalinity	S	130	100	99	87
	B	140	100	99	87
Fe	S	<0.05	<0.05	<0.05	<0.05
	B	<0.05	<0.05	<0.05	<0.05
Cl	S	1.0	2.0	2.5	<2.5
	B	1.0	2.0	2.3	<2.5
pH	S	7.5	8.4	8.2	8.6
	B	7.4	8.3	8.2	8.6
Conductivity at 25 C (umhos/cm)	S	280	220	210	185
	B	295	220	210	185
TDS	S	182	143	137	120
	B	192	143	137	120
Na	S	3.4	2.5	2.7	2.8
	B	3.3	2.9	2.5	2.7
Ca	S	44	33	34	26
	B	46	33	34	26
Mg	S	7.3	6.0	6.3	10.0
	B	8.3	5.5	6.3	7.8
SO_4	S	12	*	*	12
	B	11	*	*	12
Colour (Hazen)	S	8	12	16	11
	B	11	12	15	11

[1] All concentrations expressed in mg/l unless stated otherwise.

Table 4.7 Chlorophyll sampling at Station M1, Mica Lake, 1982[1]. ** denotes "no results".

Parameter	Sampling Date		
	1982.05.20	1982.07.13	1982.09.21
Chlorophyll a	**	3.5	**
Secchi (m)	2.9	2.0	3.3

[1] All concentrations in ug/l.

Table 4.8 Nutrient sampling at Station M1, Mica Lake, 1982[1].
* denotes "sampling error".
S denotes surface sample.
E denotes euphotic zone composite sample.
B denotes bottom sample.

Parameter		Sampling Date			
		1982.01.27	1982.05.20	1982.07.13	1982.09.21
NH_3	S	0.45			
	E		<0.01	0.01	<0.01
	B	0.62	<0.01	0.04	0.02
TKN	S	0.81			
	E		0.42	0.46	0.89
	B	1.10	0.29	0.61	0.51
NO_2	S	<0.002			
	E		0.004	<0.002	<0.002
	B	<0.002	0.002	<0.002	<0.002
NO_3	S	0.02			
	E		<0.02	<0.02	<0.02
	B	<0.02	<0.02	<0.02	<0.02
Total P	S	0.014			
	E		0.011	0.012	0.026
	B	0.018	0.006	0.012	0.008
Sol. P	S	0.004			
	E		0.002	<0.002	0.002
	B	0.004	0.004	0.002	0.004

[1] All concentrations in mg/l.

4.3 OPINICON LAKE

Water quality was sampled on January 27, May 19, July 12, and September 20, 1982.

4.3.1 Routine profiling

Quarterly temperature and oxygen profiles for Opinicon Lake are shown in Figures 4.5 and 4.6. Although there was no well defined summer thermocline, during July, oxygen concentrations dropped below 4 mg/l at depths greater than 6 m.

Levels of pH, at all depths and seasons, were within the recommended range (Table 4.9).

4.3.2 Standard chemicals

All standard chemical concentrations were below suggested criteria (Table 4.10).

4.3.3 Heavy metals

- see Section 3.4.3.

4.3.4 Chlorophyll

The mean chlorophyll a concentration fo May and July sampling (1.5 ug/l) apparently is unrepresentative of the lake's trophic status (Table 4.11). More intensive chlorophyll sampling carried out under the Cottager's Self Help Program has demonstrated that Lake Opinicon is mesotrophic (MOE 1977, MOE 1978b, MOE 1981b).

4.3.5 Nutrients

The mean total phosphorous concentration in the euphotic zone during the ice-free period (0.014 mg/l) exceeded the level recommended for a high degree of protection against aesthetic deterioration, but was below the level supporting nuisance algal blooms (Table 4.12).

There was a buildup of most nutrients in the hypolimnion over the summer months, an indicator of eutrophication.

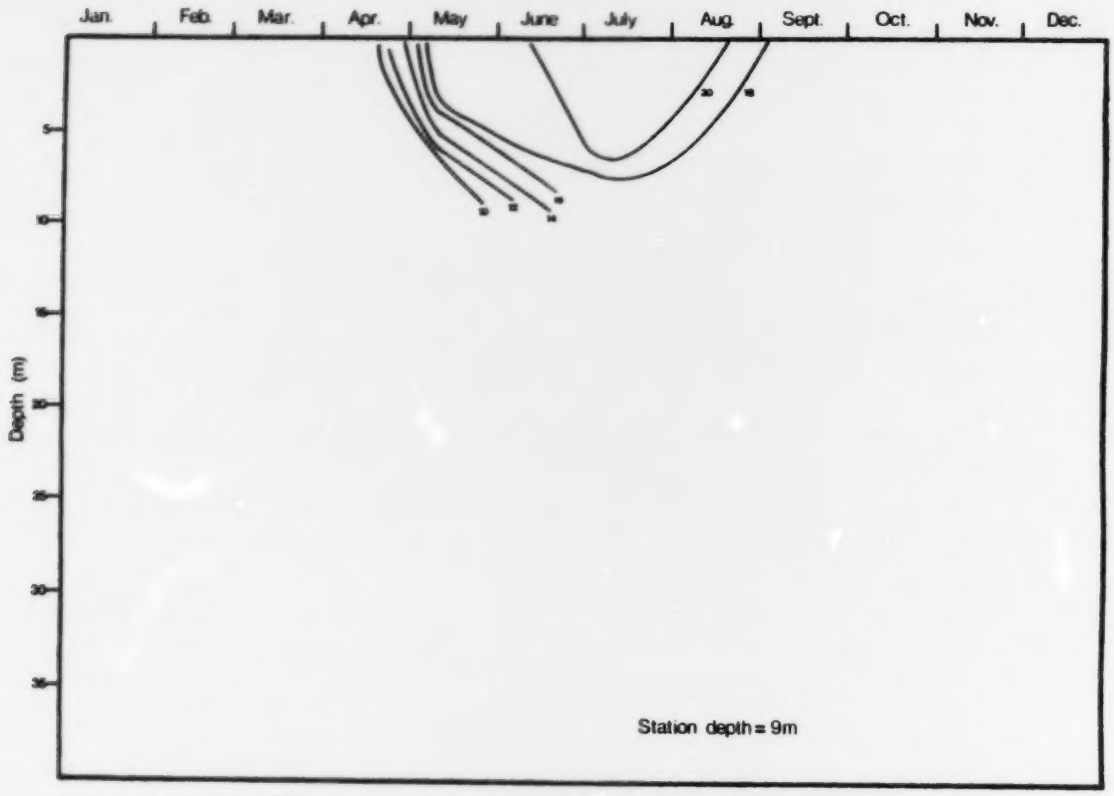


Figure 4.5 Temperature (^{o}C) isotherms at Station 01, Opinicon Lake, 1982.

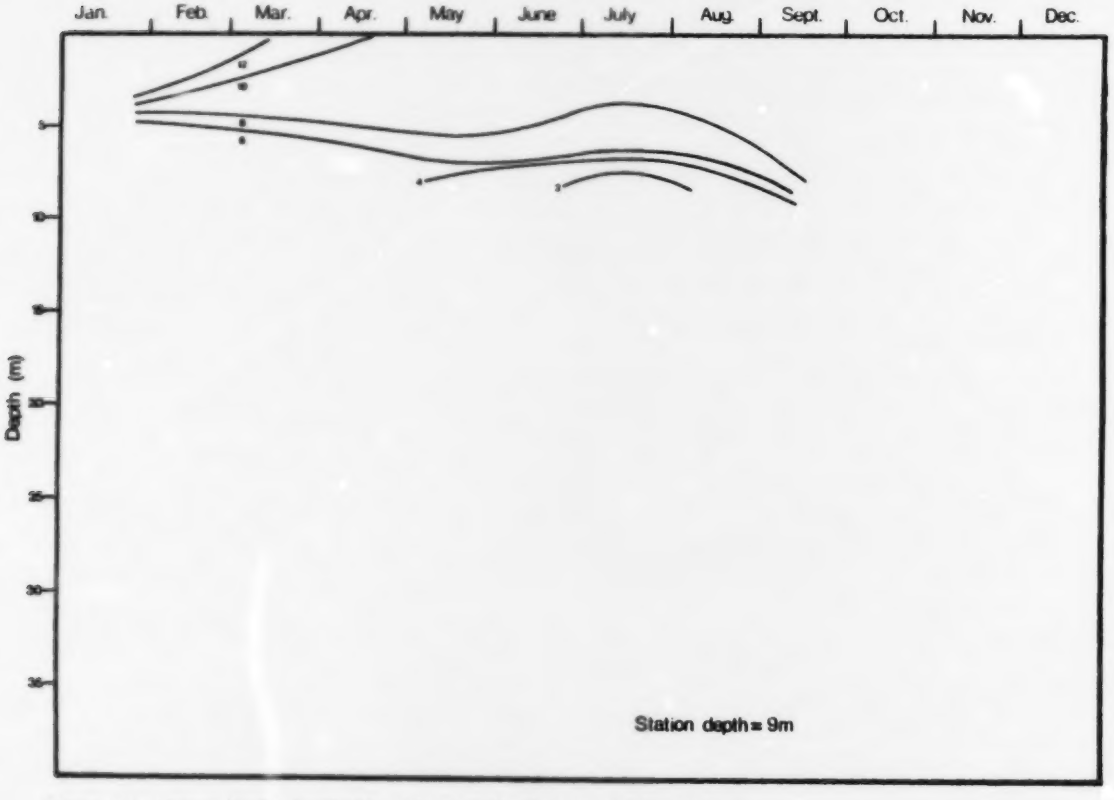


Figure 4.6 Oxygen (mg/l) isopleths at Station 01, Opinicon Lake, 1982.

Table 4.9 Routine profiling of pH at Station 01, Opinicon Lake, 1982.
* denotes "sampling error"

Depth (m)	pH			
	1982.01.27	1982.05.19	1982.07.12	1982.09.20
Surface	----	*	8.07	8.38
1	7.43	*	8.06	8.36
2	7.49	*	8.04	8.32
3	7.50	*	8.02	8.29
4	7.46	*	8.01	8.25
5	7.29	*	7.95	8.22
6	7.17	*	7.84	8.16
7	7.16	*	7.03	8.15
8			6.83	

Table 4.10 Standard chemical sampling at Station 01, Opinicon Lake, 1982[1].
* denotes "sampling error".
S denotes surface sample.
B denotes bottom sample.

Parameter		Sampling Date			
		1982.01.27	1982.05.19	1982.07.12	1982.09.28
Hardness	S	108	83	90	88
	B	112	83	90	102
Alkalinity	S	95	83	83	83
	B	104	76	82	83
Fe	S	<0.05	0.05	<0.05	<0.05
	B	<0.05	0.05	<0.05	<0.05
Cl	S	6.0	4.3	5.5	5.2
	B	4.0	4.5	5.5	5.0
pH	S	7.3	8.0	8.0	8.0
	B	7.2	7.5	7.7	7.9
Conductivity at 25 C (umhos/cm)	S	230	185	180	190
	B	230	185	185	185
TDS	S	150	120	117	124
	B	150	120	120	120
Na	S	5.3	3.7	3.8	4.0
	B	4.0	3.6	3.7	3.9
Ca	S	34	27	28	26
	B	37	27	28	24
Mg	S	5.3	3.5	4.8	5.3
	B	4.8	3.5	4.8	10.0
SO_4	S	10	*	*	9
	B	8	*	*	9
Colour (Hazen)	S	25	14	15	19
	B	16	19	22	18

[1] All concentrations expressed in mg/l unless stated otherwise.

Table 4.11 Chlorophyll sampling at Station 01, Opinicon Lake, 1982[1].
** denotes "no results"

Parameter	Sampling Date		
	1982.05.19	1982.07.12	1982.09.20
Chlorophyll *a*	1.0	2.0	**
Secchi (m)	3.0	3.1	3.0

[1] All concentrations in ug/l.

Table 4.12 Nutrient sampling at Station 01, Opinicon Lake, 1982[1].
* denotes "sampling error".
S denotes surface sample.
E denotes euphotic zone composite sample.
B denotes bottom sample.

Parameter		Sampling Date			
		1982.01.27	1982.05.19	1982.07.12	1982.09.20
NH_3	S	0.08			
	E		0.02	<0.01	0.02
	B	0.08	0.02	0.04	0.03
TKN	S	0.47			
	E		*	0.39	0.47
	B	0.37	0.33	0.45	0.47
NO_2	S	0.002			
	E		0.004	<0.002	<0.002
	B	0.002	0.002	<0.002	<0.002
NO_3	S	0.04			
	E		<0.02	<0.02	<0.02
	B	0.04	<0.02	<0.02	<0.02
Total P	S	0.008			
	E		*	0.012	0.016
	B	0.006	0.012	0.022	0.016
Sol. P	S	0.006			
	E		*	<0.002	0.004
	B	0.006	0.002	0.006	0.006

[1] All concentrations in mg/l.

4.4 SYDENHAM LAKE

Water quality was sampled on January 27, May 20, July 13, and September 21, 1982.

4.4.1 Routine profiling

Quarterly temperature and oxygen profiles for Sydenham Lake are illustrated in Figures 4.7 - 4.10. Despite a well defined summer thermocline, oxygen concentrations in the hypolimnion at Station 1 remained above 4 mg/l until September. At the shallower station (S2), concentrations stayed above 4 mg/l throughout the year.

Surface pH at Station 1 approached the upper limit of the recommended range during the summer months and was consistently higher than that in the hypolimnion (Table 4.13, 4.14). This difference in pH became more pronounced as the season progressed, indicating decomposition of organic material.

4.4.2 Standard chemicals

Water hardness at Stations S1 and S2 exceeded the desireable level, but is less than 500 mg/l, the concentration regarded as undesirable for industrial and domestic uses (Table 4.15, 4.16).

The concentrations of all other standard chemicals are below suggested criteria.

4.4.3 Heavy metals,

- see Section 3.4.3.

4.4.4 Chlorophyll

Mean chlorophyll a concentrations at Station S1 and S2 were 2.4 ug/l and 2.5 ug/l respectively, indicating that the lake is mesotrophic (Table 4.17). These results compare favourably with other studies (MOE 1977, MOE 1978b).

4.4.5 Nutrients

The mean total phosphorous concentration in the euphotic zone for the ice-free period at Station S1 (0.021 mg/l) exceeded the level supporting nuisance algal blooms. Concentrations at Station S2 (mean: 0.012 mg/l) exceeded the level recommended for a high degree of protection against aesthetic deterioration, but were still below nuisance levels (Table 4.18, Table 4.19).

The concentration of Kjeldahl nitrogen exceeded criteria during September sampling at both locations, reflecting the

decomposition of organic material.

There was a buildup in the concentration of nutrients in the hypolimnion over the summer months at Station S1, an indicator of eutrophication.

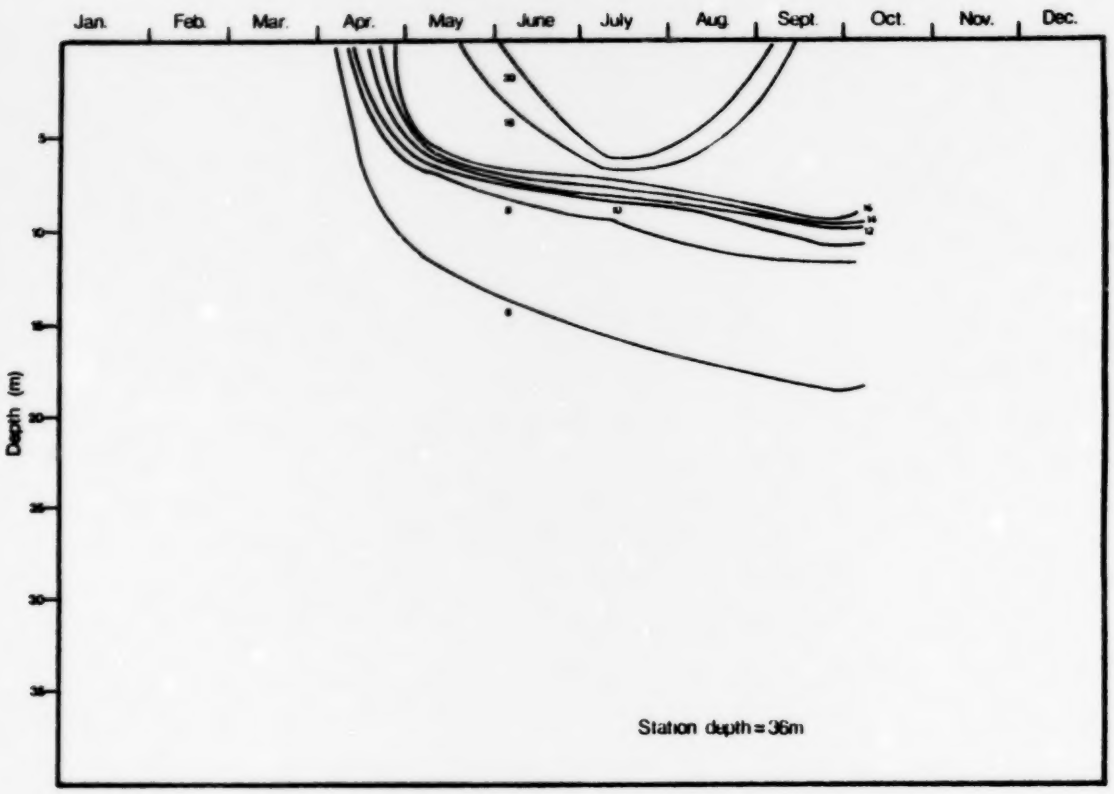


Figure 4.7 Temperature (^{0}C) isotherms at Station S1, Sydenham Lake, 1982.

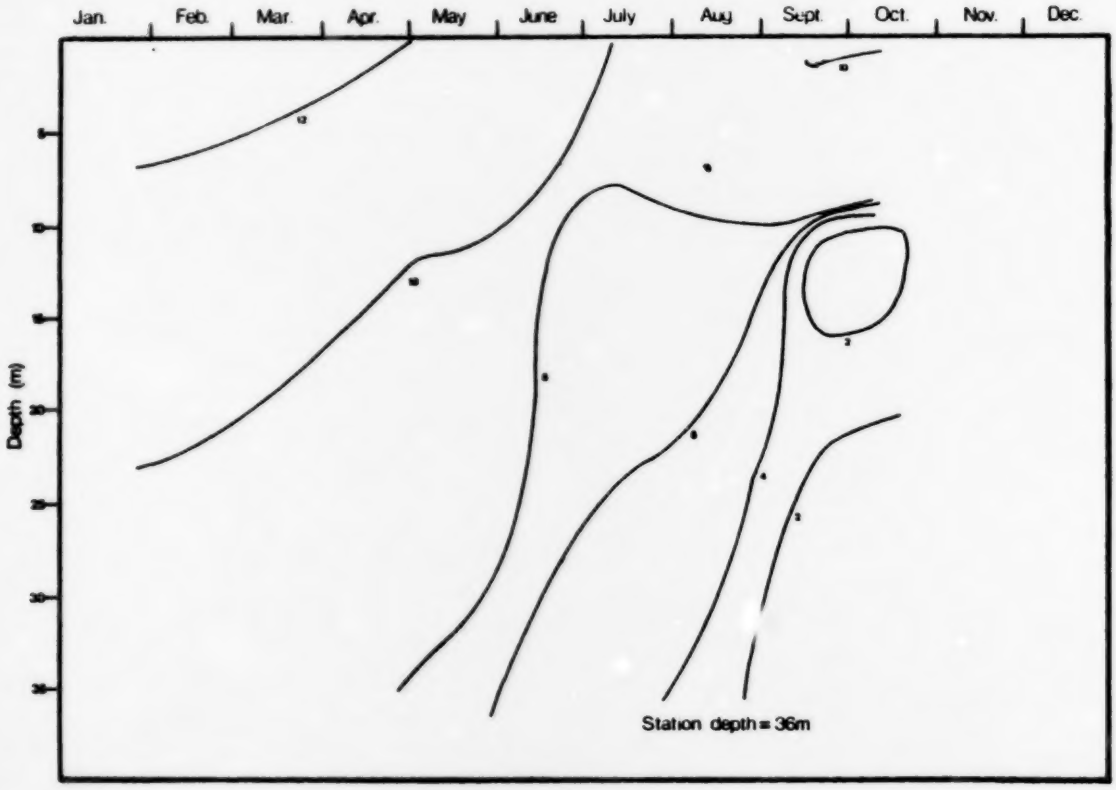


Figure 4.8 Oxygen (mg/l) isopleths at Station S1, Sydenham Lake, 1982.

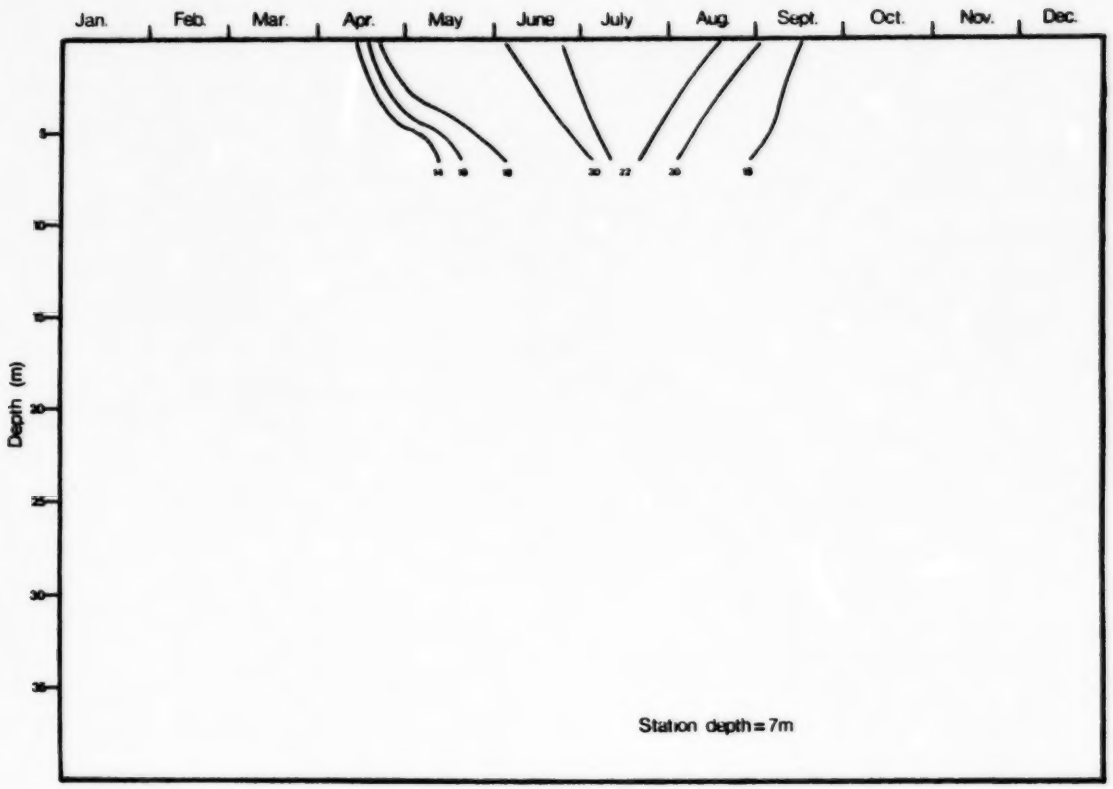


Figure 4.9 Temperature (^{o}C) isotherms at Station S2, Sydenham Lake, 1982.

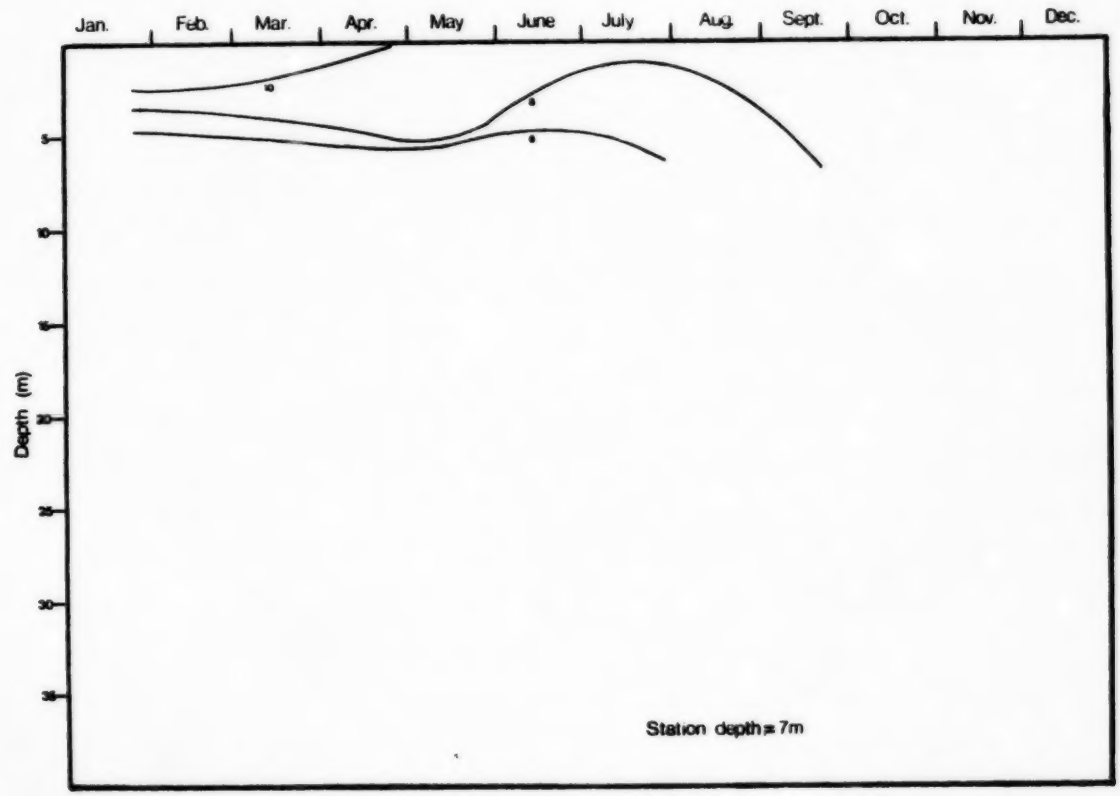


Figure 4.10 Oxygen (mg/l) isopleths at Station S2, Sydenham Lake, 1982.

Table 4.13 Routine profiling of pH at Station S1, Sydenham Lake, 1982.
* denotes "sampling error".

Depth (m)	pH			
	1982.01.27	1982.05.20	1982.07.13	1982.09.21
Surface	----	*	8.33	8.59
1	8.29	*	8.33	8.58
2	8.31	*	8.33	8.54
3	8.33	*	8.31	8.55
4	8.33	*	8.30	8.55
5	8.30	*	8.27	8.52
6	8.28	*	8.20	8.44
7	8.24	*	7.93	8.43
8	8.21	*	7.62	8.42
9	8.17	*	7.50	8.12
10	8.15	*	7.47	7.32
11	8.13	*	7.45	7.20
12	8.12	*	7.45	7.19
13	8.10	*	7.45	7.19
14	8.07	*	7.44	7.18
15	8.02	*	7.44	7.18
16	8.02	*	7.44	7.18
17	8.12	*	7.43	7.18
18	8:19	*	7.43	7.17
19	8.16	*	7.42	7.17
20	8.17	*	7.42	7.17
24	8.09	*	7.42	7.15
28	8.01	*	7.43	7.17
32	*	*	7.41	7.15
34	*	*	7.37	----
35	*	*		7.22

Table 4.14 Routine profiling of pH at Station S2, Sydenham Lake, 1982.
* denotes "sampling error".

Depth (m)	pH			
	1982.01.27	1982.05.20	1982.07.13	1982.09.21
Surface	----	8.21	8.17	8.25
1	7.77	8.21	8.14	8.23
2	7.81	8.13	8.09	8.24
3	7.70	*	8.07	8.21
4	7.56	*	8.02	8.19
5	7.47	*	8.02	8.19
6		*	7.79	7.98

Table 4.15 Standard chemical sampling at Station S1, Sydenham Lake, 1982[1].
* denotes "sampling error".
S denotes surface sample.
B denotes bottom sample.

Parameter		Sampling Date			
		1982.01.27	1982.05.20	1982.07.13	1982.09.21
Hardness	S	136	131	126	122
	B	142	132	140	144
Alkalinity	S	124	120	113	111
	B	131	126	126	135
Fe	S	<0.05	<0.05	<0.05	0.10
	B	<0.05	<0.05	<0.05	<0.20
Cl	S	9.0	9.6	9.3	9.0
	B	9.0	9.0	9.5	8.7
pH	S	7.8	8.5	8.3	8.4
	B	7.6	7.7	7.3	7.6
Conductivity at 25 C (umhos/cm)	S	280	270	250	245
	B	295	280	280	295
TDS	S	182	176	163	159
	B	192	182	182	192
Na	S	6.0	5.4	5.5	5.3
	B	6.3	5.5	5.6	5.5
Ca	S	42	37	37	32
	B	45	38	41	40
Mg	S	7.3	9.0	8.3	10.0
	B	7.3	8.5	9.2	11.0
SO_4	S	10	*	*	10
	B	10	*	*	10
Colour (Hazen)	S	12	16	15	16
	B	16	20	16	38

[1] All concentrations expressed in mg/l unless stated otherwise.

Table 4.16 Standard chemical sampling at Station S2, Sydenham Lake, 1982[1].
* denotes "sampling error".
S denotes surface sample.
B denotes bottom sample.

Parameter		Sampling Date			
		1982.01.27	1982.05.20	1982.07.13	1982.09.21
Hardness	S	140	132	124	120
	B	156	133	122	124
Alkalinity	S	125	117	113	114
	B	143	124	112	113
Fe	S	<0.05	0.05	<0.05	<0.05
	B	<0.05	0.05	<0.05	<0.05
Cl	S	6.0	6.8	7.0	6.2
	B	6.0	7.3	7.3	6.2
pH	S	7.6	8.1	8.0	8.2
	B	7.4	7.7	8.0	8.1
Conductivity at 25 C (umhos/cm)	S	295	265	235	240
	B	310	280	235	240
TDS	S	192	172	153	156
	B	202	182	153	156
Na	S	4.8	4.2	4.0	4.2
	B	5.5	4.6	4.0	4.3
Ca	S	42	40	34	33
	B	46	41	34	33
Mg	S	8.7	7.8	9.2	9.2
	B	9.7	7.5	8.7	10.0
SO_4	S	11	*	*	9
	B	11	*	*	9
Colour (Hazen)	S	18	15	17	19
	B	18	18	17	19

[1] All concentrations expressed in mg/l unless stated otherwise.

Table 4.17 Chlorophyll sampling at Station S1 and S2, Sydenham Lake, 1982[1].
** denotes "no results".

Parameter	Sampling Date					
	1982.05.20		1982.07.13		1982.09.21	
	S1	S2	S1	S2	S1	S2
Chlorophyll *a*	2.7	1.4	2.0	3.5	**	**
Secchi (m)	1.9	2.2	4.1	3.2	3.1	3.0

[1] All concentrations in ug/l.

Table 4.18 Nutrient sampling at Station S1, Sydenham Lake, 1982[1].
* denotes "sampling error".
S denotes surface sample.
E denotes euphotic zone composite sample.
B denotes bottom sample.

Parameter		Sampling Date			
		1982.01.27	1982.05.20	1982.07.13	1982.09.21
NH_3	S	0.04			
	E		<0.01	0.03	0.01
	B	0.09	<0.01	*	0.20
TKN	S	0.38			
	E		0.39	0.44	0.52
	B	0.37	0.39	*	0.69
NO_2	S	0.002			
	E		0.002	0.002	<0.002
	B	0.002	0.002	*	0.052
NO_3	S	0.04			
	E		<0.02	0.34	<0.02
	B	0.06	<0.02	*	0.36
Total P	S	0.014			
	E		0.006	0.042	0.016
	B	0.016	0.006	*	0.070
Sol. P	S	0.004			
	E		0.004	0.026	0.002
	B	0.006	0.002	*	0.052

[1] All concentrations in mg/l.

Table 4.19 Nutrient sampling at Station S2, Sydenham Lake, 1982[1].
* denotes "sampling error".
S denotes surface sample.
E denotes euphotic zone composite sample.
B denotes bottom sample.

Parameter		Sampling Date			
		1982.01.27	1982.05.20	1982.07.13	1982.09.21
NH_3	S	0.09			
	E		<0.01	0.02	0.02
	B	0.15	0.01	0.03	0.04
TKN	S	0.43			
	E		0.31	0.43	0.46
	B	0.42	0.42	0.42	0.53
NO_2	S	0.002			
	E		0.002	<0.002	<0.002
	B	0.002	0.002	<0.002	<0.002
NO_3	S	0.02			
	E		<0.02	<0.02	<0.02
	B	0.02	<0.02	<0.02	<0.02
Total P	S	0.012			
	E		0.010	0.014	0.012
	B	0.006	0.014	0.012	0.012
Sol. P	S	0.006			
	E		0.002	<0.002	<0.002
	B	0.004	<0.002	<0.002	0.004

[1] All concentrations in mg/l.

4.5 UPPER RIDEAU LAKE

Water quality was sampled on January 26, May 17, July 12 and September 20, 1982.

4.5.1 Routine profiling

Oxygen and temperature profiles are for Upper Rideau Lakes are illustrated in Figures 4.11 and 4.12. The lake had a well defined summer thermocline. During July sampling, oxygen concentrations were less than 4 mg/l at depths greater than 10 m.

Although surface pH values were consistently higher than those from the hypolimnion, differences became more pronounced as the season progressed (Table 4.20). These lower pH conditions are related to organic decomposition (MOE 1971).

4.5.2 Standard chemicals

The concentration of iron in spring bottom samples exceeded criteria. All other standard chemical concentrations were below recommended values (Table 4.21).

4.5.3 Heavy metals

- see Section 3.4.3.

4.5.4 Chlorophyll

Chlorophyll a concentrations were low during May and July sampling (1.9 and 2.2 ug/l) (Table 4.22). Unfortunately, missing data prevents the calculation of an ice-free period mean and precludes trend analysis.

MOE (1971 and 1977) reported that although Upper Rideau chlorophyll concentrations were low from May to July, moderately high values developed in August, while nuisance levels were present during September, ie. 5 ug/l.

4.5.5 Nutrients

The average total phosphorous concentration in the euphotic zone during the ice-free period (0.018 mg/l) exceeded the level recommended for a high degree of protection against aesthetic deterioration. Concentrations of total phosphorous during July and September sampling were capable of supporting nuisance algal blooms (Table 4.23).

There was a buildup of most nutrients in the hypolimnion over the summer months, an indicator of eutrophication.

4.5.6 Runoff studies

Runoff samples were collected at the Westport inflow channel on April 15, 1982, during the walleye spawning run.

Although the alkalinity concentration was slightly depressed during runoff, pH remained within acceptable levels for walleye egg incubation (Table 4.24).

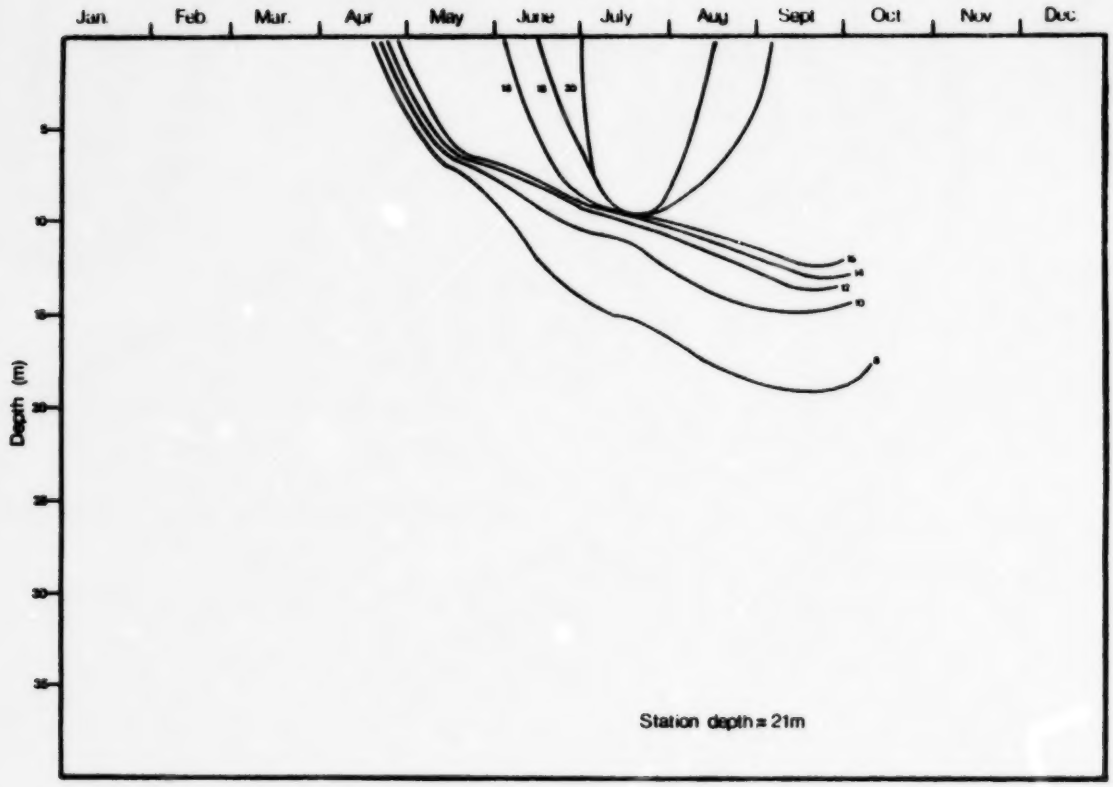


Figure 4.11 Temperature (^{o}C) isotherms at Station URI, Upper Rideau Lake, 1982.

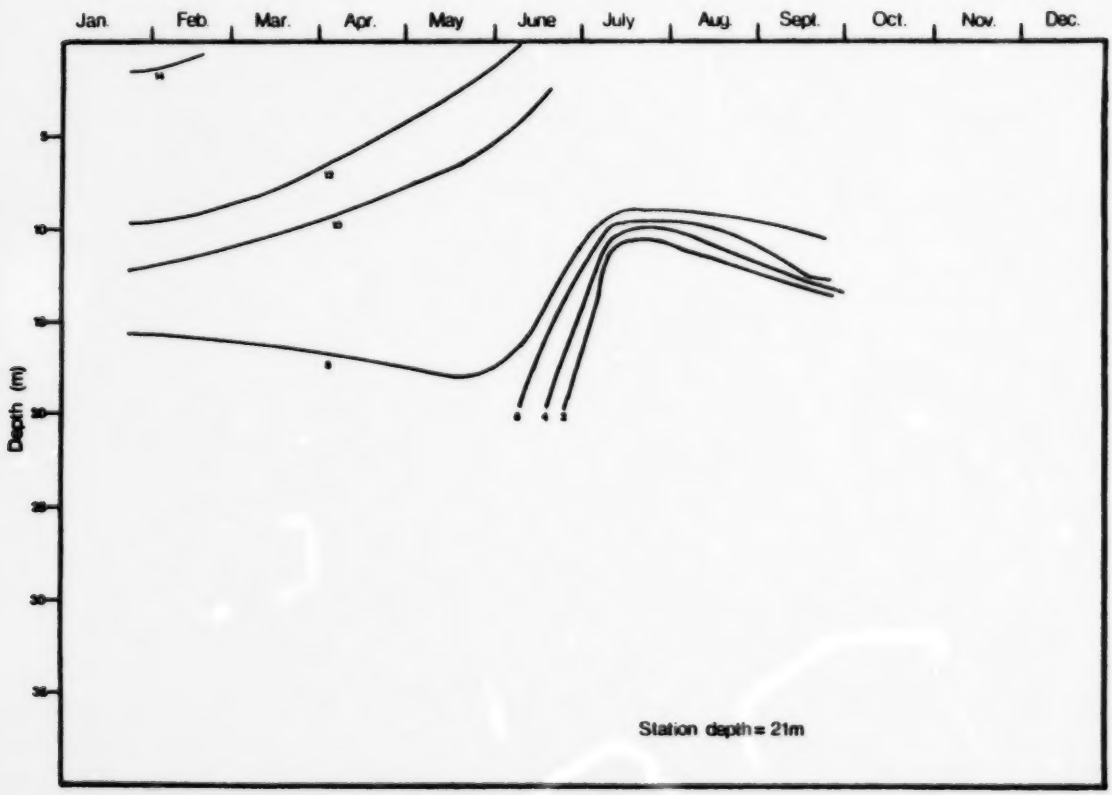


Figure 4.12 Oxygen (mg/l) isopleths at Station URI, Upper Rideau Lake, 1982.

Table 4.20 Routine profiling of pH at Station U1, Upper Rideau Lake, 1982.

Depth (m)	pH			
	1982.01.26	1982.05.17	1982.07.12	1982.09.20
Surface	----	8.64	8.00	8.04
1	8.21	8.64	8.02	8.04
2	8.20	8.65	8.01	8.03
3	8.20	8.66	8.00	8.02
4	8.20	8.66	8.00	8.01
5	8.19	8.66	8.00	8.00
6	8.16	8.66	8.00	7.99
7	8.11	7.83	7.99	7.99
8	8.05	7.76	7.98	7.98
9	8.03	7.70	7.97	7.99
10	7.94	7.70	7.11	7.98
11	7.88	7.70	7.01	7.97
12	7.79	7.69	7.00	7.68
13	7.67	7.65	6.98	6.97
14	7.62	7.67	6.98	6.85
15	7.60	7.67	6.97	6.83
16	7.56	7.66	6.97	6.81
17	7.53	7.64	6.97	6.82
18	7.50	7.57	6.97	6.77
19	7.46	7.52	6.95	6.74

Table 4.21 Standard chemical sampling at Station U1, Upper Rideau Lake, 1982[1].
* denotes "sampling error".
S denotes surface sample.
B denotes bottom sample.

Parameter		Sampling Date			
		1982.01.26	1982.05.17	1982.07.12	1982.09.20
Hardness	S	111	100	104	104
	B	116	102	108	110
Alkalinity	S	101	96	102	110
	B	105	85	104	111
Fe	S	<0.05	<0.05	<0.05	<0.05
	B	<0.05	0.40	<0.05	<0.05
Cl	S	9.0	9.3	9.8	8.7
	B	9.0	9.0	9.3	8.5
pH	S	7.6	8.1	8.1	8.7
	B	7.4	7.5	7.5	7.3
Conductivity at 25 C (umhos/cm)	S	245	230	220	225
	B	250	235	230	245
TDS	S	159	150	143	146
	B	163	153	150	159
Na	S	6.0	6.0	5.8	5.5
	B	6.6	5.9	5.8	6.0
Ca	S	34	33	33	31
	B	35	33	33	34
Mg	S	6.3	4.0	5.3	6.3
	B	6.8	5.0	6.3	5.8
SO_4	S	10	*	*	11
	B	9	*	*	9
Colour (Hazen)	S	12	12	11	15
	B	14	19	24	24

[1] All concentrations expressed in mg/l unless stated otherwise.

Table 4.22 Chlorophyll sampling at Station U1, Upper Rideau Lake, 1982[1].
** denotes "no results"

Parameter	Sampling Date		
	1982.05.17	1982.07.12	1982.09.20
Chlorophyll a	1.9	2.2	**
Secchi (m)	2.2	3.0	3.3

[1] All concentrations in ug/l.

Table 4.23 Nutrient sampling at Station U1, Upper Rideau Lake, 1982[1].
* denotes "sampling error".
S denotes surface sample.
E denotes euphotic zone composite sample.
B denotes bottom sample.

Parameter		Sampling Date			
		1982.01.26	1982.05.17	1982.07.12	1982.09.20
NH_3	S	0.06			
	E		<0.01	0.01	0.05
	B	0.21	0.14	0.08	0.58
TKN	S	0.46			
	E		0.33	0.41	0.54
	B	0.43	0.45	0.47	0.45
NO_2	S	0.002			
	E		0.002	<0.002	0.002
	B	<0.002	0.006	<0.002	0.006
NO_3	S	0.04			
	E		<0.02	<0.02	<0.02
	B	0.06	0.09	0.20	<0.02
Total P	S	0.012			
	E		0.012	0.020	0.022
	B	0.022	0.016	0.070	0.172
Sol. P	S	0.008			
	E		0.004	0.002	0.002
	B	0.014	0.008	0.054	0.164

[1] All concentrations in mg/l.

Table 4.24 Runoff sampling at Westport Spawning Channel, Upper Rideau Lake, 1982[1].

Parameter	Sampling Date
	1982.04.15
Conductivity (umhos/cm)	200
pH	7.7
Alkalinity (as $CaCO_3$)	84

[1] All concentrations expressed in mg/l unless otherwise stated.

5. RECOMMENDATIONS

The collection-analysis-reporting arrangements with MOE should be followed-up more closely to prevent lost data. The immediate review of data sheets from MOE will permit us to identify both anomalous results and misplaced samples, perhaps allowing samples to be rerun before being disposed of at the laboratory.

Chlorophyll a and heavy metal samples should be checked for particulate matter at time of collection. If particulate matter is present, another sample should be collected farther from the bottom.

The sampling frequency for nutrients and chlorophyll a should be increased; perhaps in conjunction with existing creel census programs.

6. ACKNOWLEDGEMENTS

The Ministry of the Environment, Southeastern Region, again provided analytical and technical support. Their continued cooperation is greatly appreciated.

We wish to acknowledge the valuable contribution of RLFAU and Ontario Career Action Program (OCAP) seasonal staff who assisted with the collection, verification and compilation of field data, ie. George Lily, Gary Ridout, and Jim Boraski.

Thanks also to Leslie Cronk, who typed an earlier draft, and to Karen Stinchcombe who processed the final manuscript. Gary Ridout drafted the final figures.

Paul Bewick, Ross Claytor and Reg Genge provided constructive comments and criticisms of earlier drafts.

7. REFERENCES

Bailey, R.M., J.E. Fitch, E.S. Herald, E.A. Lachner, C.C. Lindsay, C.R. Robbins and W.B. Scott. 1970. A list of common and scientific names of fishes. Third Edition. Am. Fish. Soc. Special Publication No. 6. 150p.

Breder, C.M. and D.E. Rosen. 1966. Modes of reproduction in fishes. The Natural History Press, New York. 941p.

Canada- Ontario Rideau - Trent - Severn Study Committee (CORTS). 1971. The Rideau - Trent Severn, Canada's unique 425-mile waterway corridor. Yesterday, Today, Tomorrow. A report of optimum recreational development. Information Canada. 75p.

Casselman, J.M. 1978. Effects of environmental factors on growth, survival, activity, and exploitation of northern pike, Esox lucius. Am. Fish. Soc. Spec. Publ. 11: 114-128.

Chamberlain, A.J., T. Kellar, and D. Maraldo. 1980. Water quality requirements for sport fishes of the Grand River watershed: A literature review. Grand River Basin Water Management Study. Technical Report Series. Report #13. Prepared for Grand River Implementation Committee by Ont. Min. Nat. Res., Cambridge, Ontario. 111p.

Chapman, L.J. and D.E. Putman. 1966. The Physiography of Southern Ontario. 2nd edition. University of Toronto Press, Toronto, Ontario. 386p.

Coutant, C.C. 1975. Temperature selection by fish: A factor in powerplant impact assessments. p.575-597. In: Environmental effects of cooling systems at nuclear power plants. Int. Atomic Energy Agency, Vienna.

Dillon, P. 1981. Acid precipitation in Ontario study. Acid sensitivity survey of lakes in Ontario. March 1981. Ont. Min. Envir., Limnology and Toxicity Section.

Dodge, D.P., G.A. Goodchild, J.C. Tilt, and D.G. Waldriff. 1981. Manual of instructions: Aquatic habitat inventory systems. Ont. Min. Nat. Res., Fisheries Branch, Toronto. 168p.

Edmondson. W.T. 1979. Lake Washington and the predictability of limnological events. Arch. Hydrobiol. Beih. Ergegn. Limnol. 13: 234-241.

Energy, Mines and Resources. 1978. Topographical map 31 C/16, Perth, Ontario. Edition 3. Dept. Energy, Mines and Resources. Surveys and Mapping Branch, Ottawa.

1979a. Topographical map 31 C/7, Sydenham, Ontario. Edition 6. Dept. Energy, Mines and Resources. Surveys and

Mapping Branch, Ottawa.

1979b. Topographical map 31 C/9, Westport, Ontario. Edition 5. Dept. Energy, Mines and Resources. Surveys and Mapping Branch, Ottawa.

Environment Canada. 1979. Water quality source-book. A guide to water quality parameters. Environment Canada. 89p.

Environmental Protection Agency (U.S.). 1977. Quality criteria for water. Office of Water and Hazardous Materials, U.S. Environmental Protection Agency, Washington, D.C. 256p.

Ferguson, R.G. 1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. J. Fish. Res. Board Can. 15: 607-624.

Gale, G.E. and G.A. Goodchild. 1982. Review and reformulation of the relationship between standard conductance and total dissolved solids. Ont. Min. Nat. Res., Environmental Dynamics Section, Fisheries Branch. 41p. & app.

Hart, J.S. 1952. Geographic variation of some physiological and morphological characters in certain freshwater fish. Univ. Toronto Stud. Biol. Ser. No. 60, Publ. Ont. Fish. Res. Lab. No. 72: 79p.

Horning, W.B. and R.E. Pearson. 1973. Growth temperature requirements and lower lethal temperatures for juvenile smallmouth bass (Micropterus dolomieui). J. Fish Res. Board Can. 30: 1226-1230.

MacLean, N.G. and W.G. Smith. 1981. Five-year operational plan. Ont. Min. Nat. Res., Rideau Lakes Fisheries Assessment Unit. File Report No. 2. 14p.

MacLean, N.G. and W.G. Smith. 1982. Water quality programme: Field instructions. Ont. Min. Nat. Res., Rideau Lakes Fisheries Assessment Unit. File Report No. 6. 11p.

McKee, J.E. and H.W. Wolf. 1971. Water quality criteria. 2nd edition. Res. Agency, Calif. Water Res. Control Board. Publ. 3-A. Sacremento, California. 548p.

Neill, W.H. 1971. Distributional ecology and behavioral thermoregulation of fishes in relation to heated effluent from a steam-electric power plant (Lake Monona, Wisconsin). Ph.D. thesis, Univ. Wisc., Madison, Wisc. 203p.

Ontario Ministry of the Environment. 1971. Report on water quality in Upper Rideau Lake. Ont. Min. Env., Recreational Lakes Program, Southeastern Region. 37p.

1977. Cottagers self-help program. Enrichment status of seventy-nine lakes in the Southeastern Region of Ontario. Ont. Min. Env., Technical Support Section, Southeastern Region. 62p.

1978a. Water management. Goals, policies, objectives and implementation procedures of the Ministry of the Environment. Ont. Min. Env., Water Resources Branch. 67p.

1978b. Cottagers self-help program. Enrichment status of sixty-nine lakes in the Southeastern Region of Ontario. Ont. Min. Env., Technical Support Section, Southeastern Region. 70p. & app.

1979. Determination of the susceptibility to acidification of poorly buffered surface waters. Ont. Min. Env., Limnology and Toxicity Section. Water Resources Branch. 67p.

1981a. Outlines of analytical methods. Ont. Min. Env., Water Quality Section. Laboratory Services Branch. 246p. + app.

1981b. Cottagers self-help program. Enrichment status of lakes in Southeastern Region of Ontario. Ont. Min. Env., Technical Support Section, Southeastern Region. 62p.

Ontario Ministry of Natural Resources. 1973. Watershed Divisions, Southern Ontario. Map M6273. Ont. Min. Nat. Res., Surveys and Mapping Branch.

1982. Partitioning yields from the morphoedaphic index into individual species yields. Ont. Min. Nat. Res., Report of SPOF working group number twelve. Strategic Planning for Ontario fisheries. Policy development. 71p.

Raine, G.E. 1970. An analysis of the Upper Rideau Lake yellow pickerel fishery. Ont. Dept. Lands and Forests. Kemptville District Internal Report. 38p.

Robbins W.H. and H.R. MacCrimmon. 1974. The black bass in North America and overseas. Biomanagement and Research Enterprises. Sault Ste. Marie, Ont., Canada. 196p.

Schlesinger, D.A., G.E. Ridout and N.G. MacLean. 1984. The Sport Fisheries of Long, Mica, Opinicon, Sydenham and Upper Rideau Lakes. 1982. Ont. Min. Nat. Res., Rideau Lakes Fisheries Assessment Unit. Report No. 9. 60p.

Smith, L.L. Jr., and W.M. Koenst. 1975. Temperature effects on eggs and fry of percoid fishes. EPA Ecol. Res. Ser. EPA-660/3-75-107. U.S. Environ. Prot. Agency, Wash. D.C. 91p.

Smith, W.G. and N.G. MacLean. 1984. Water quality assessment of Big Clear, Big Rideau, Big Salmon, Charleston, and Devil Lakes, 1981. Ont. Min. Nat. Res., Rideau Lakes Fisheries Assessment Unit. Report No. 5. 77p.

Stiebel, W.N. 1975. A hydrogeochemical survey of Mica Lake, near Sydenham, Ontario. Dept. Geol. Sci., Queen's University, BSc. thesis. 97p.

Thurston, R.V., R.C. Russo, and C.E. Smith. 1978. Acute toxicity of ammonia and nitrite to cutthroat trout fry. Trans. Amer. Fish. Soc. 107: 361-168.

Westin, D.T. 1974. Nitrate and nitrite toxicity to salmonid fishes. Prog. Fish-Cult. 36: 86-89.

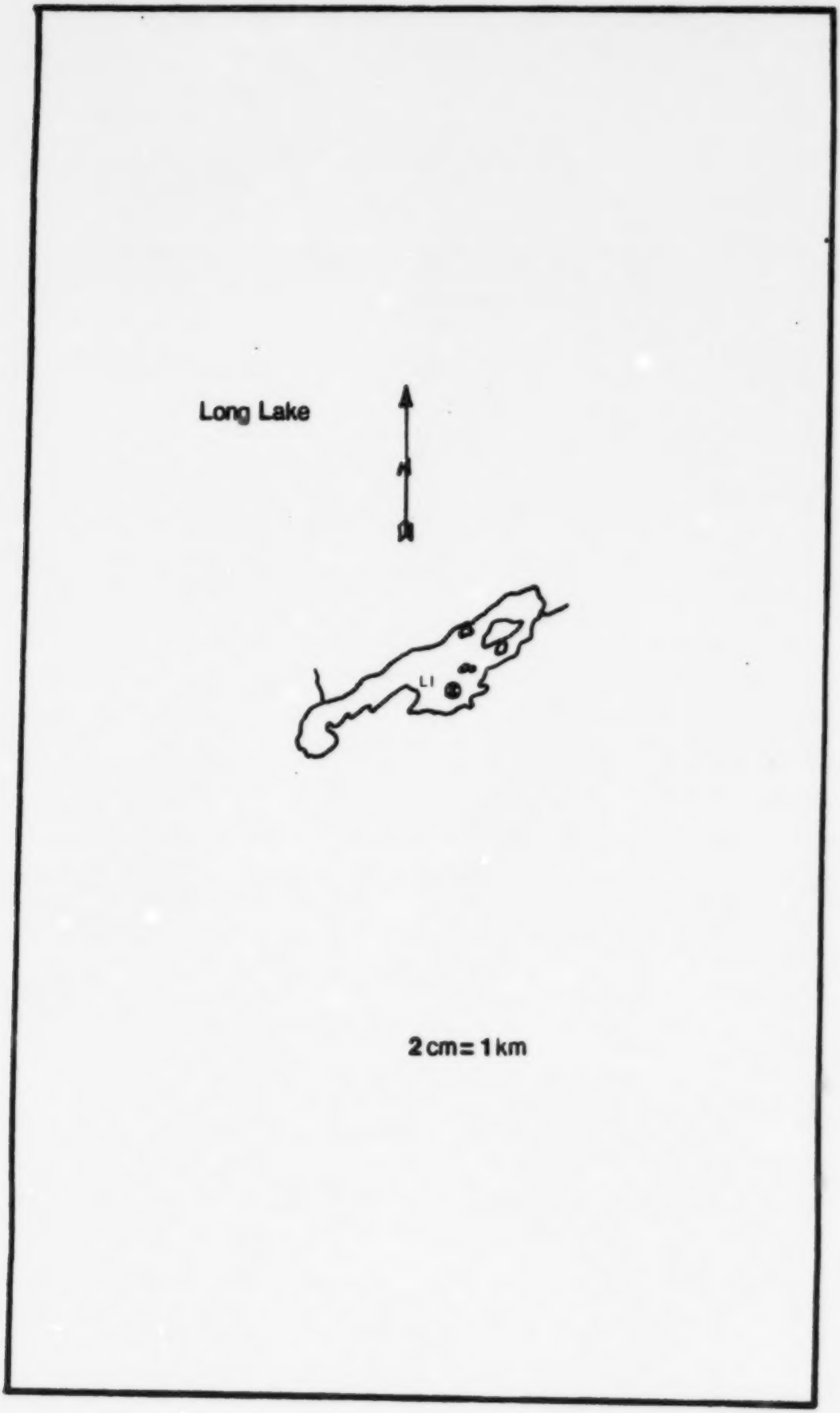
PERSONAL COMMUNICATIONS

Genge, R.E. Water Quality Technician. Technical Support Section, Southeastern Region. Ont. Min. Envir., Kingston, Ontario.

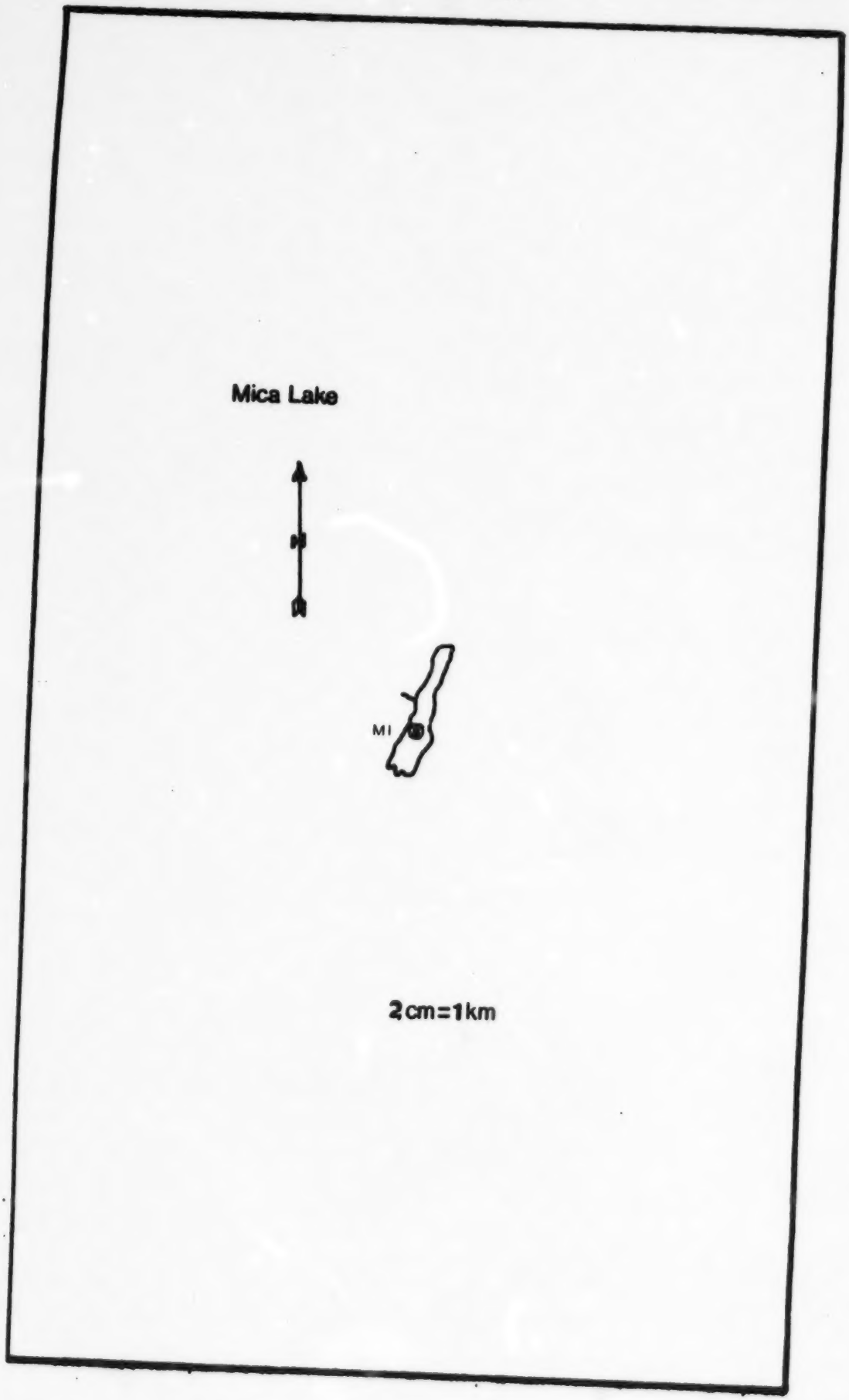
8. APPENDICES

8.1 WATER QUALITY STATIONS

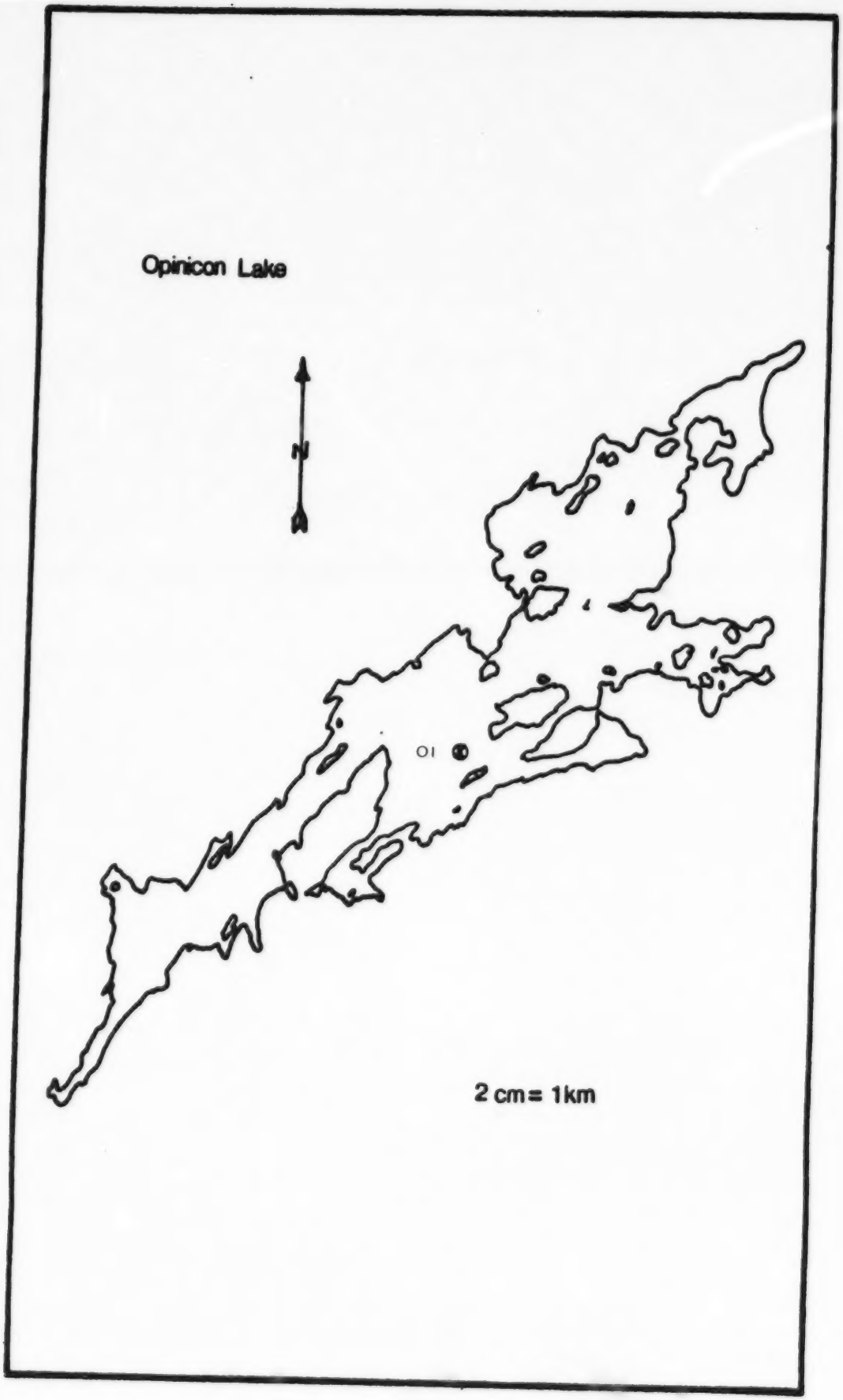
a) Long Lake
b) Mica Lake
c) Opinicon Lake
d) Sydenham Lake
e) Upper Rideau Lake



Appendix 8.1 a.



Appendix 8.1 b.

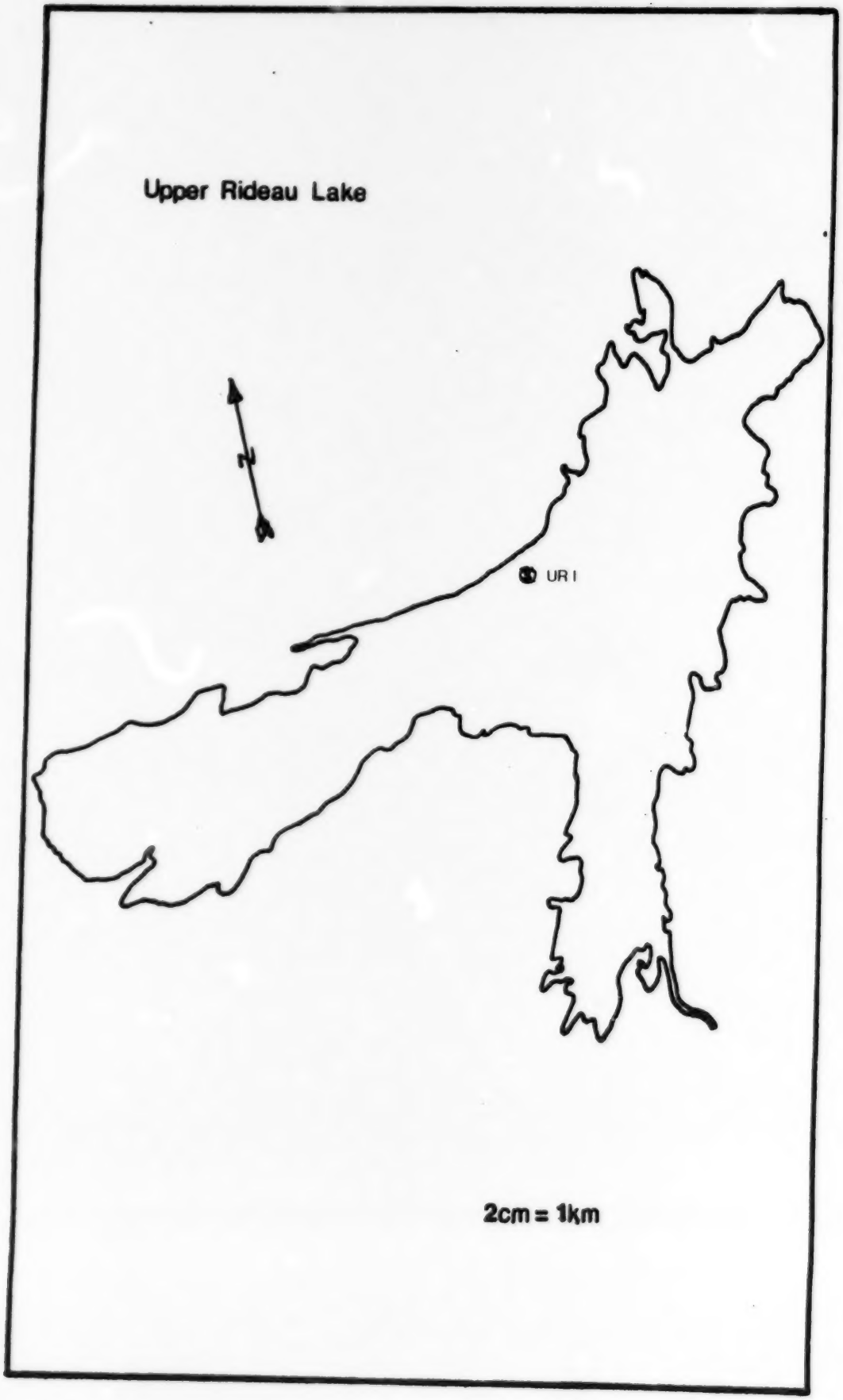


Appendix 8.1 c.

Sydenham Lake

2cm = 1km

Appendix 8.1 d.



Appendix 8.1 e.

3419
(100 PR. 85 11 27)
ISSN 0828-1564
ISBN 0-7729-0882-6